AIR ENGINES

Volume Two

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Pulse motor permits low-speed, high-torque operation

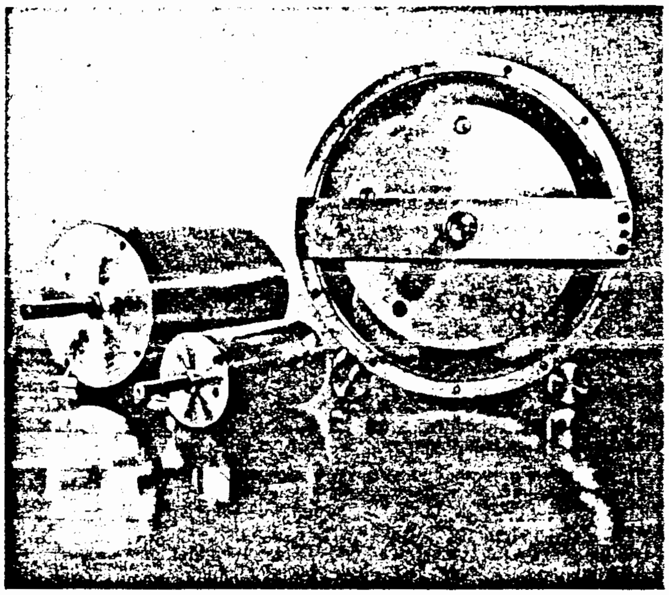
Motor runs on air, oil, freshwater or seawater

David J. Bak, East Coast Editor

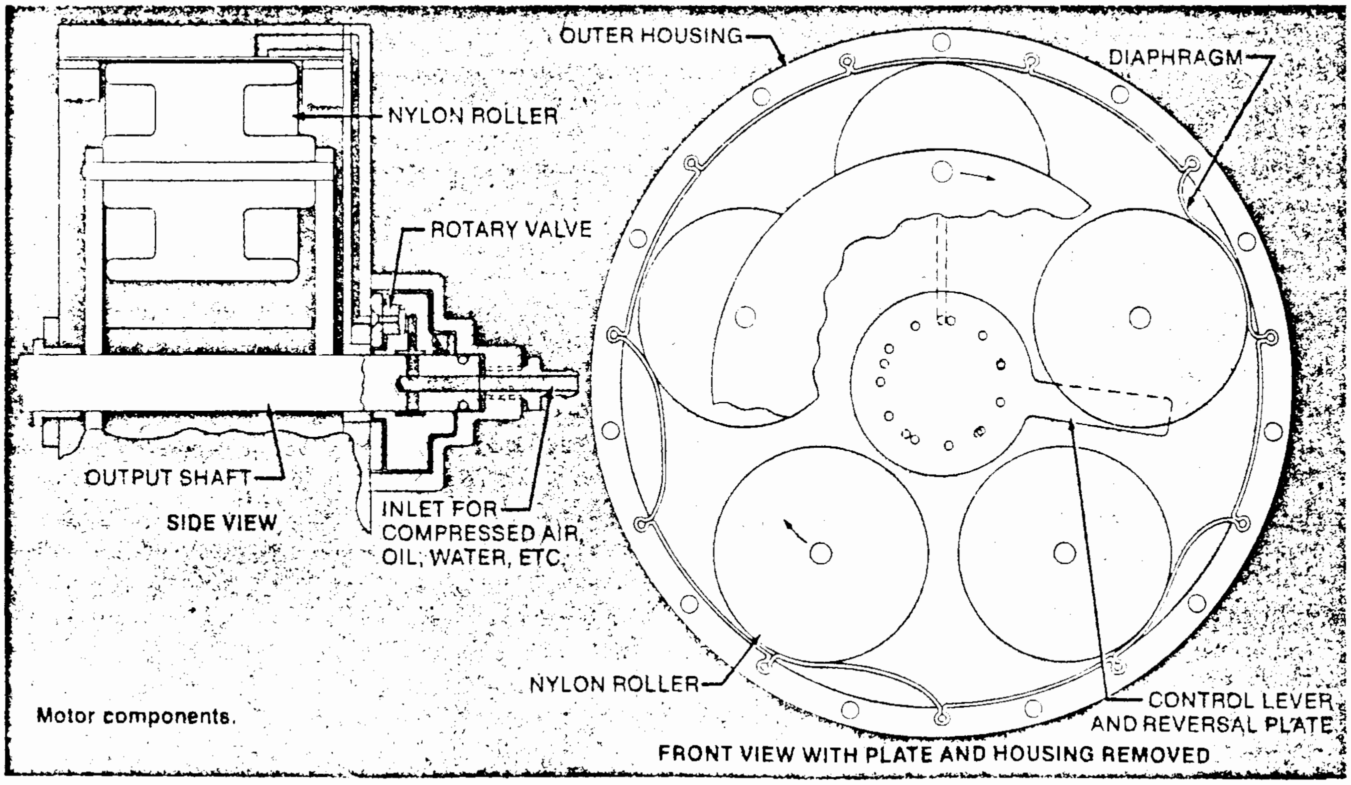
New York, NY—A diaphragm-operated pulse motor, developed specifically to reduce air consumption and increase efficiency, overcomes the shortcomings of rotary-vane and piston-type air motors. Vane- and piston-air motors generally use a high volume of air for horsepower and torque produced. The diaphragm pulse motor doesn't. Furthermore, the pulse motor has no rubbing parts so it requires no lubrication. This absence of friction allows all types of unclean air, water and foreign particles (even sand) to run through the motor without causing damage. The motor can be driven by oil, freshwater or seawater just as easily as by air.

Invented by Jerome Murray of The Jerome Murray Corp., the diaphragm pulse motor is constructed of only seven major parts: outer housing, roller cage, rotary valve, control lever and reversal plate, rollers and diaphragm. The single-piece diaphragm fits between the outer housing and the open roller cage in such a manner that the diaphragm is divided or segmented into a series of diaphragms. The rollers, connected to the motor's output shaft, are fitted inside the cage and are acted upon by the diaphragms. The diaphragms, in turn, are activated by the driving fluid.

The operating principle of motor is simple. Compressed air (or water under pressure) is fed into channels in the motor's outer housing via a rotary valve, expanding the diaphragm segments sequentially. When inflated, each diaphragm segment forms a hill under the roller, forcing it to rotate in the cage. The number of rollers and timing are such that several rollers are under



Pulse motor has no close tolerances, resulting in low manufacturing costs. Also, 90% of motor can be manufactured in plastic.


OUTER HOUSING
DIAPHRAGM
NYLON ROLLER
ROTARY VALVE
OUTPUT SHAFT
SIDE VIEW
INLET FOR COMPRESSED AIR, OIL, WATER, ETC.
NYLON ROLLER
CONTROL LEVER AND REVERSAL PLATE
FRONT VIEW WITH PLATE AND HOUSING REMOVED

Motor components.

pressure at all times. A control lever connected to a reversal plate can be used to reverse the rotation of the motor. This is done by altering the timing of diaphragm expansion relative to roller position.

Because the motor has no close tolerances, there are no limits to motor size. The smallest motor to date measures 2½ inches in diameter by 3 inches in length, and uses 10 cfm driving fluid. It produces 2.7 lb-ft at 80 psi and develops 0.172 hp at 2250 rpm. The largest motor so far is 10 inches in diameter by 4 inches in length. At 80 psi it develops 9 hp with a stall torque of 50 lb-ft. The motor weighs only 20 lb as compared to a 9-hp vane motor that weighs approximately 69 lb.

With slight modifications the pulse motor can also be used as a brake, clutch or pump.

Additional details. Write......THE
JEROME MURRAY CORPORATION, 10
Orben Drive, Landing NJ 07850
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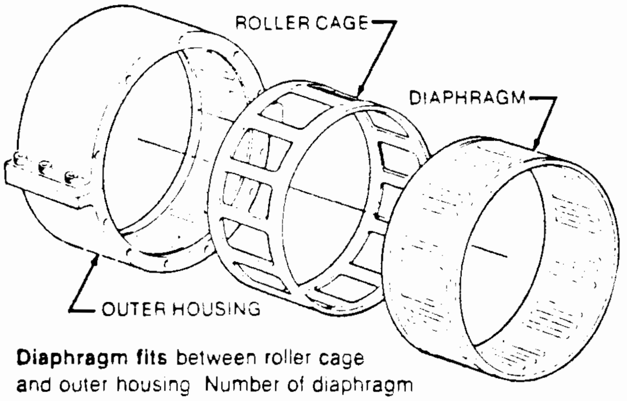
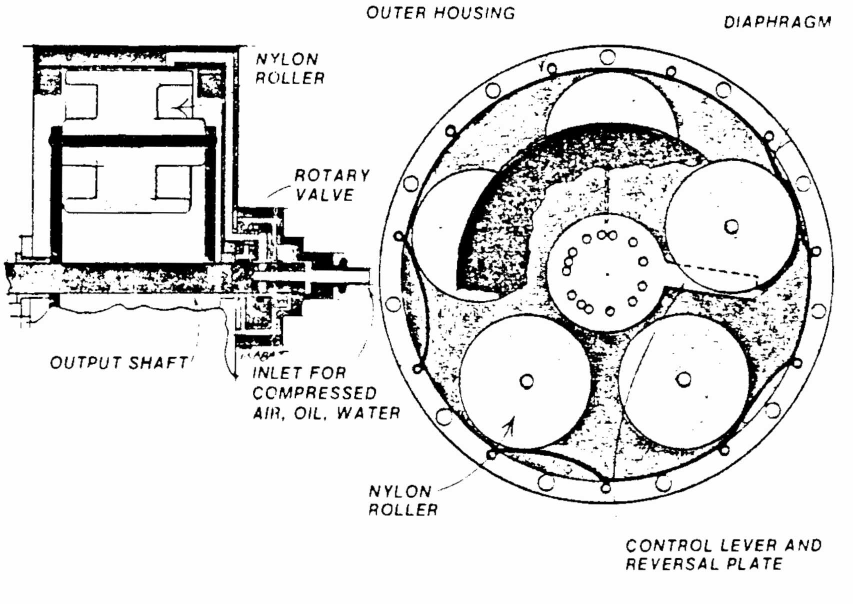
Diaphragm life is extremely long. Motors that have run for over 9000 hr show no diaphragm fatigue.



Diaphragm fits between roller cage and outer housing. Number of diaphragm segments equals twice number of rollers plus one.

Expanding diaphragm powers pulse motor

This new motor uses compressed air or pressurized fluid fed into passages in the motor's outer housing via a rotary valve. Fluid or air expands sections of a diaphragm that produce a crowbar action on nylon rollers, forcing them to rotate a roller assembly and, thus, the output shaft. The timing arrangement allows several rollers to be under pressure at all times, and a control lever allows motor speed to be reduced without reducing pressure to maintain constant torque output. Because of this design, the motor requires 40% to 60% less cfm of air per unit horsepower output than conventional air motors. There are no rubbing parts, so lubrication in the air stream and other associated maintenance is eliminated. The exhausted air, since it contains no oils, does not have to be vented from the worksite. The absence of rubbing parts also allows the motor to be driven by all types of unclean fluids and air, including slurries and salt water. The Pulse Air motor develops its highest torque at low rpm and, thus, does not need a final drive gear reduction. According to **The Jerome Murray Corp.** 10 Orben Dr. Landing, NJ 07850, prototypes of the motor have been run for over 9000 hr without signs of wear. For licensing information, **circle 574.**



VAN DEN BOSSCHE--- An eminent Belgian engineer- invented the Van Den Bossche cycle. French patent# 610,033 Described in French journal "ChaLeur et Industrie" June 15, 1928. This is a 95% as opposed to normally 20% efficient steam engine.

March 31, 1931. J. J. VAN DEN BOSSCHE **1,798,566**

STEAM TURBINE

Filed Aug. 27, 1925 2 Sheets-Sheet 1

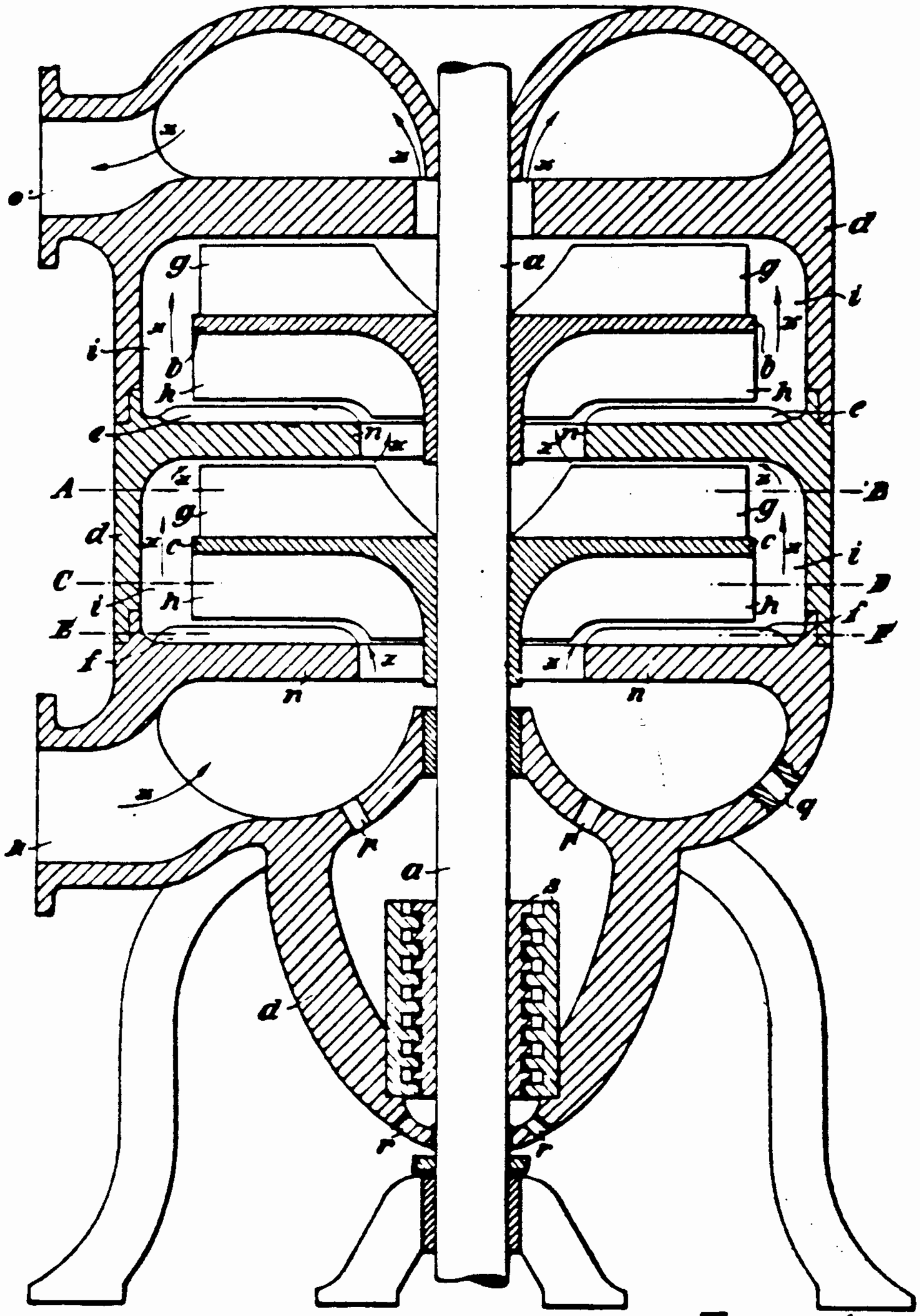


Fig. 1.

Inventor
J. J. Van den Bossche
By
Atty

NOTE SIMILARITIES TO TESLA TURBINE

March 31, 1931. J. J. VAN DEN BOSSCHE 1,798,566

STEAM TURBINE

Filed Aug. 27, 1925 2 Sheets-Sheet 2

Fig. 2.

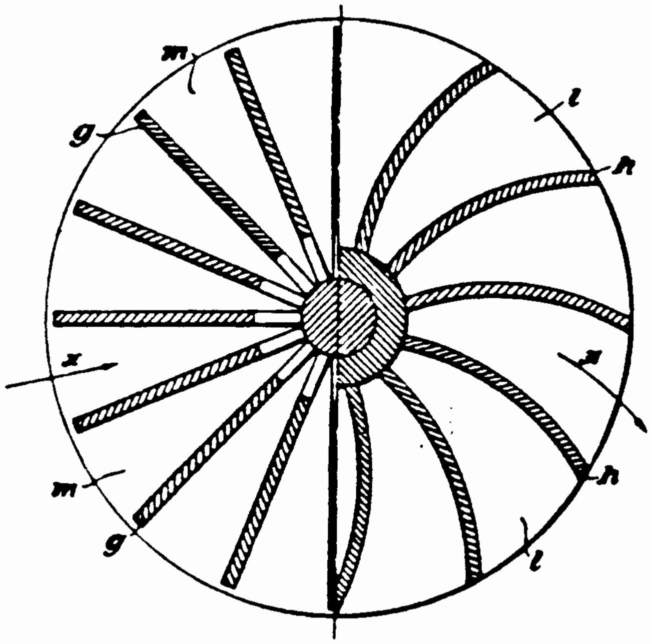
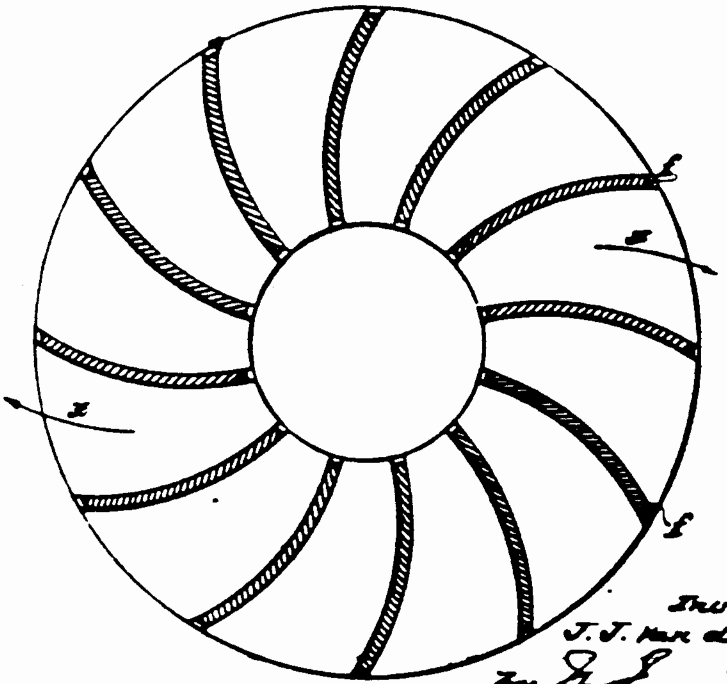


Fig. 3.



Inventor
J. J. Van den Bossche
By
Atty.

Patented Mar. 31, 1931 **1,798,566**

UNITED STATES PATENT OFFICE

JEAN JOSEPH VAN DEN BOSSCHE, OF ENGHIEN, BELGIUM

STEAM TURBINE

Application filed August 27, 1925, Serial No. 52,936, and in Germany August 28, 1924.

My invention relates to a multi-stage turbine and provides an improved structure which is based on the fact that heat can be directly transformed into kinetic energy. In the turbine according to my present invention the temperature of the flowing steam is decreased not solely by expansion but by considerably extending the way the steam is compelled to take and by subjecting the steam to the action of centrifugal force. In the practical embodiment of my invention, which will be described hereinafter, the flowing steam is conducted alternately along a radial outward and a radial inward path and during each reversal is subjected to the influence of centrifugal force. It is by these combined means that almost no steam leaves the turbine at the exit end, but all steam consumed is condensed into water which is used as a sealing agent taking a counter flow to the direction of the steam and being collected and tapped at the steam entrance end of the turbine. The immediate result of my present method of transforming the heat of the steam directly into kinetic energy is the fact that there are no other losses of heat than those which occur accidentally by radiation, conductibility, and leakages which, however, can be reduced as much as possible.

My invention is illustrated diagrammatically and by way of an example in the accompanying drawing in which Figure 1 is an axial section through a vertical two-stage steam turbine devised according to this invention; Figure 2 shows two horizontal sections through one of the rotors, the lefthand half of the figure being a section in the plane A—B of Fig. 1, and the righthand half a section in the plane C—D of Fig. 1; and Figure 3 is a horizontal section in the plane E—F of Fig. 1.

Referring to the drawing, *a* denotes a vertical shaft to which are keyed a number of disks of which two, *b* and *c*, are shown. These disks are bladed on both sides. *d* is the casing, *n* are annular partition walls bearing curved guide blades *e* and *f* on their upper faces (Fig. 3) and in opposition to blades *h* of the wheel disks *c* and *b*. I prefer to have these blades *h* curved as shown in the right hand half of Fig. 2. The compartments formed around each set of bladed disks or wheels leave at the circumference of the latter chambers *i* in which the steam is subjected to the action of the centrifugal force. Between two adjacent wheels, inner annular steam chambers are formed by openings in the partition walls *n*. The path followed by the steam entering at the inlet branch *k* to the outlet branch *o*, as indicated by arrows *x*. The steam flows radially outwards when passing along the blades *h* of the first and second stage, and radially inwards when passing along the turbine blades *g*. The steam is thereby compelled to cover a long way and to remain a long time in the turbine under the action of centrifugal force in conjunction with the heat depriving influence of the casing walls of the turbine, and imparts to the blades *h* and *g* a part of the kinetic energy released by the decrease of its temperature. The temperature and pressure of the steam will drop from one stage to another. In Fig. 2, *m* denotes the passages between the turbine blades *g* which can be curved, too. Within these passages the kinetic energy of the steam molecules flowing towards the inner steam chambers is taken up by the blades *g*.

The condensed water which accumulates in the turbine as a result of the direct transformation of heat into motive power is being thrown radially outwards against the circumferential walls of the chambers *i* and then passes between the guide blades *e* and *f* to the center openings of the walls *n*. Finally, the condensed water collects in the lowermost part of the casing *d* from where it may be returned to the boiler through passages *p*, *q*, *r*. As the condensed water is moving in opposition to the flow of the steam within the vertical turbine, it serves also as a sealing agent and thus prevents leakages of steam.

As the steam is to be condensed above boiling point in the turbine, no steam-jacket or the like is required for the casing of the same.

The turbine may be worked with ordinary wet steam or with dry steam or with superheated steam, and it may be live steam, exhaust-steam, or steam given off by boiling water within the turbine. If a part of the steam remains uncondensed it escapes through the branch *o* and may either be sucked off by means of an ice-cooled condensing pot or be conducted back to the boiler by means of a cooled compressor or a so-called extractor. A part of the water of condensation escaping through the passages *p* may be used as sealing means in the labyrinth packing *s* from which it escapes through the orifices *r*.

From the above it may be seen that the turbine is intended to carry into practice a method for converting steam into motive power in such a manner that the amount of heat contained in the steam is converted into kinetic energy without any rest. The condensed water is flowing through the turbine in a direction opposite to that of the steam so that a certain counter-current is produced and maintained; in other words, the steam and the condensed water penetrate one another whereby the condensed water is heated nearly to boiler-temperature, in consequence whereof this water can be used very economically as boiler feed-water.

I wish it to be understood that the improved turbine described in the preceding paragraphs may be built also as a turbine with horizontal shaft.

My improved steam-turbine may be used in connection with industrial plants of any kind, as well as for driving ships, and it can be used also in connection with vehicles of any kind, especially motor-vehicles, turbine-locomotives, and the like, and I deem it capable for use also in connection with air-craft where boilers with instantaneous steam-generation are employed, as has been proposed and is intended.

I claim:

1. In a turbine, the combination of a casing having an inlet and an outlet for the motive fluid, a shaft, turbine wheels fixedly mounted thereon, each turbine wheel consisting of a disk and radial blades on both sides of said disk and extending over its entire surface, radially extending partition walls within said casing, whereby a compartment is formed for each of said double bladed turbine wheels, said compartments being of the same size throughout said casing and having equally sized annular passages around each turbine wheel, said partition walls leaving central steam passages of the same size throughout said casing.

2. In a turbine, the combination of a casing having an inlet and an outlet for the motive fluid, a shaft, turbine wheels fixedly mounted thereon, each turbine wheel consisting of a disk and radial blades on both sides of said disk and extending over its entire surface, radially extending partition walls within said casing, whereby a compartment is formed for each of said double bladed turbine wheels, said compartments being of the same size throughout said casing and leaving equally sized annular passages around each turbine wheel, said partition walls leaving central steam passages of the same size throughout said casing, and stationary guide blades upon said partition walls and opposite those of said radial blades through which the steam flows radially outwards.

3. In a turbine, the combination of a casing having an inlet and an outlet for the motive fluid, a vertically arranged shaft, turbine wheels fixedly mounted thereon, each turbine wheel consisting of a disk and radial blades on both sides of said disk and extending over its entire surface, a vertically extending casing, radially extending partition walls within said casing, whereby a compartment is formed for each of said double bladed turbine wheels, said compartments being of the same size throughout said casing and leaving equally sized passages around each turbine wheel, said partition walls leaving central steam passages of the same size throughout said casing, at the base of said casing a collecting trough for condensed water descending in opposite direction to the flowing steam, and discharge openings within said collecting trough.

In testimony whereof I affix my signature.

JEAN JOSEPH VAN DEN BOSSCHE.

U.S. Patent #4,076,471

Very few moving parts, minimum surface to wear.

No exploding gas at 4,300°F. The low high temperature of 651°F = ½ million miles for good citizen before a major overhaul. A true rotary with dble. duty pistons running around in circles!!

One size Ulti-Engine, different initial pressurizations for subcompact to luxury car to five ton truck.

McClure's Ultimate Lever Engine plus Stirling Cycle

NON-POLLUTING - EXTERNAL COMBUSTION - WHISPER QUIET

ULTI-ENGINE

APPETITE OF A PIGMY, POWER OF A GIANT!
100 mpg PROPANE - 10 hp. PER CU. IN.!!

Converts all pressure to useful work!

Stirling's cycle invented in 1816 has finally met it's mate, Mc Clure's Ultimate Lever Engine! This polluted world need not wait longer. The solution to pollution is in this REVOLUTION!!!

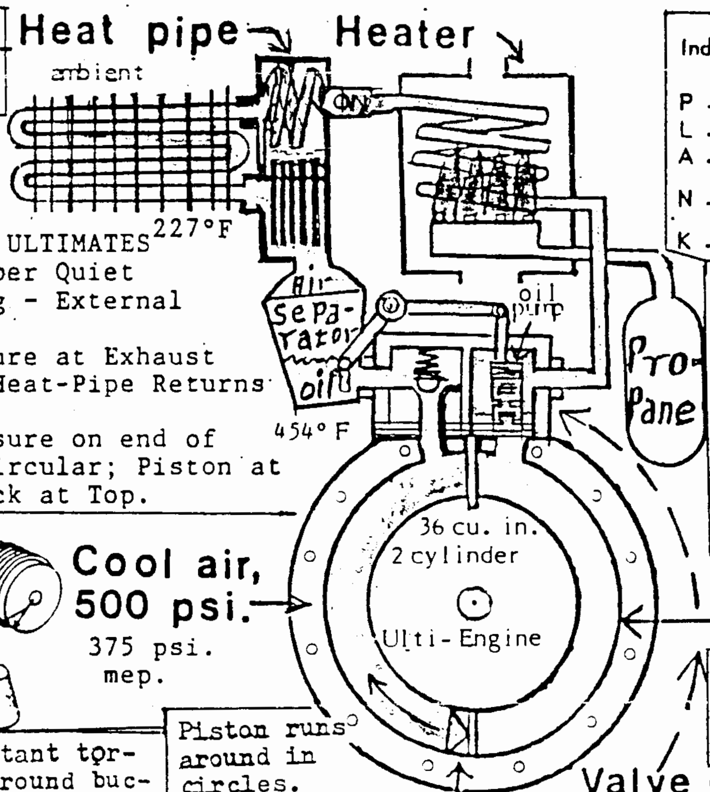
Ulti-Engine!!
Ulti-Engine!!

$$\begin{array}{l} \quad P \qquad\qquad L \qquad\qquad A \qquad\qquad N \qquad\qquad K \\ 375 \text{ psi} \times 1.5' \times 1 \text{ sq.}'' \times 13{,}607 \times 2 = 15{,}307{,}875 \div 33{,}000 = \underline{464} \text{ ihp} \end{array}$$

Hot air pushes & cold air pulls on the piston = Double Acting.

$$\text{Indicated Horsepower (ihp)} = \frac{\text{PLANK}}{33{,}000}$$

P - mep in lbs. per sq. in.
L - length of the stroke in feet
A - cylinder area in sq. in.
N - power strokes per min.
K - number of cylinders

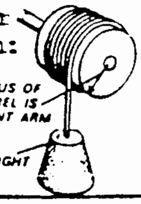


An aluminum Ulti-Engine & pressure system has 26.5 lb. of aluminum & 40 lb. iron for a total 66.5 lb. = 7 hp/ lb. A cast-iron Ulti-Engine & pressure system weighs 125 lb. = 3.75 hp/ lb. Needs no tranny as such, only forward, neutral and reverse. Propane burns at 1200° F. Heat-pipes can returne 73 % of the heat to the system.

ULTI-ENGINE'S 6 ULTIMATES

1. Quiet - Whisper Quiet
2. Non-Polluting - External Combustion
3. Zero - Pressure at Exhaust
4. Adiabatic - Heat-Pipe Returns Heat
5. Lever - Pressure on end of
6. Cylinder - Circular; Piston at Bottom is Back at Top.

The sOlution to pollution in a revolution: an Ulti-Engine revolution.



No coolant to freeze or boil away. Only 45 seconds to operating pressure. Perfect starts in cold weather. Never over-heats.

Piston runs around in circles.

Valve closes when Piston at 180°. As piston gets to 360° volume has doubled, pressure halved = ZERO psi at exhaust!!

Solution to pollution in a REVOLUTION, in an Ulti-Engine REVOLUTION!!

To produce constant torque, wind rope around bucket on a shaft & attach a weight. Radius of bucket is a constant lever and produces constant torque as does Ulti-Engine.

Ulti-Engine = efficiency of a turbine & economy of positive expansion. Every last ounce of pressure is turned to usful work on a shaft between intake & exhaust: By 18 stage turbine, final stage 22' dia, & costs millions; By Ulti-Engine in one circular rotation & costs peanuts! Ulti-Engine is the ultimate in simplicity & efficiency! Natural law principles say Ulti-Engine will never be surpassed.

Back of piston = power piston, front = displacer. Piston is 1 sq. in. Lever = 3" = radius; dia. = 6" x 3.1416 = 18.85" = stroke. Mep = mean effective pressure or average pressure. Mc Clure's Ulti-Engine is the ideal expander as: Stirling Hot Air engine, solar engine, steam engine, external combustion engine and as internal combustion engine Ulti-Engine will run on propane, natural gas, kerosene, stove oil diesel, gasoline, coal, wood, pellets, sun heat, waste heat, even newspapers or cow manure and that's no bull! No reciprocation means 90 % less friction & 500% more power/ cu. in. for Ulti-Engine. CO_2 & water are the end products of complete combustion. Run Ulti-Engine on natural gas to make electricity free & heat the house with the waste heat. Double-duty natural gas has earned it's price.

United States Patent [19]

McClure

[11] **4,076,471**

[45] **Feb. 28, 1978**

[54] **ROTARY ENGINE WITH SEPARABLE ABUTMENT AND ADJUSTABLE VALVE CAM**

[76] Inventor: **Troy A. McClure,** General Delivery, Los Gatos, Calif. 95030

[21] Appl. No.: **698,187**

[22] Filed: **Jun. 21, 1976**

[51] **Int. Cl.**² **F01C 19/00;** F01C 1/00; F01C 21/12; F16K 31/524

[52] **U.S. Cl.** **418/143;** 418/222; 137/624.17

[58] **Field of Search** 418/222, 248, 143; 137/624.17

[56] **References Cited**

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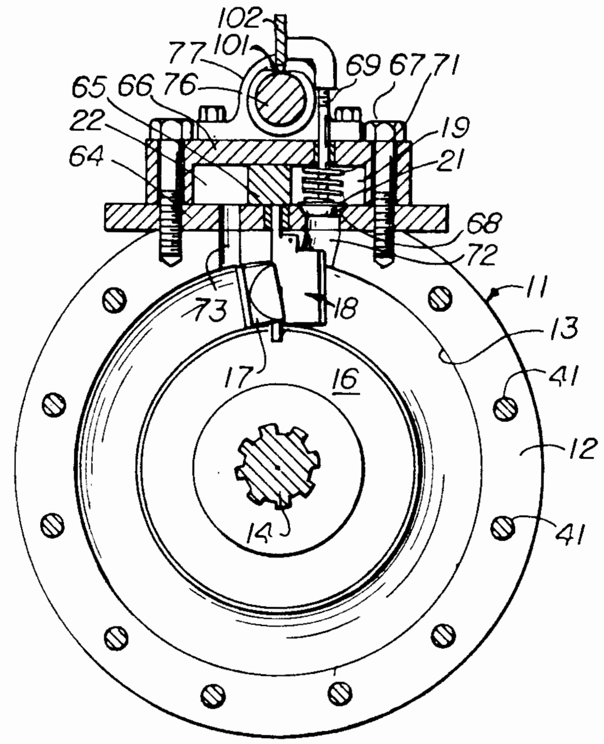
Primary Examiner—John J. Vrablik
Attorney, Agent, or Firm—Julian Caplan

[57] **ABSTRACT**

An engine comprises at least one cylinder and preferably several cylinders side-by-side. Each cylinder comprises a toroidal cylinder and has a piston which revolves around the cylinder. The piston is fixed to the periphery of a disk fixed to the main shaft which coincides with the axis of the cylinder. At one position of the cylinder a gate is installed which seals the cylinder into two sections. On one side of the gate is an inlet port and on the opposite side an exhaust port. A valve controlled by a cam shaft timed from the main shaft controls the inlet port. A gaseous medium is externally heated in a heater and is introduced under pressure through the inlet port and drives the piston around the cylinder; the medium in the cylinder ahead of the piston from the previous cycle is discharged through the exhaust port and cooled and then reheated. The valve is manually (or pedally) controlled to cut off to maintain proper speed for the load on the main shaft. The valve also cuts off intake as the piston approaches the gate. The gate is opened either by contact with the piston or other means and is closed behind the piston.

5 Claims, 10 Drawing Figures



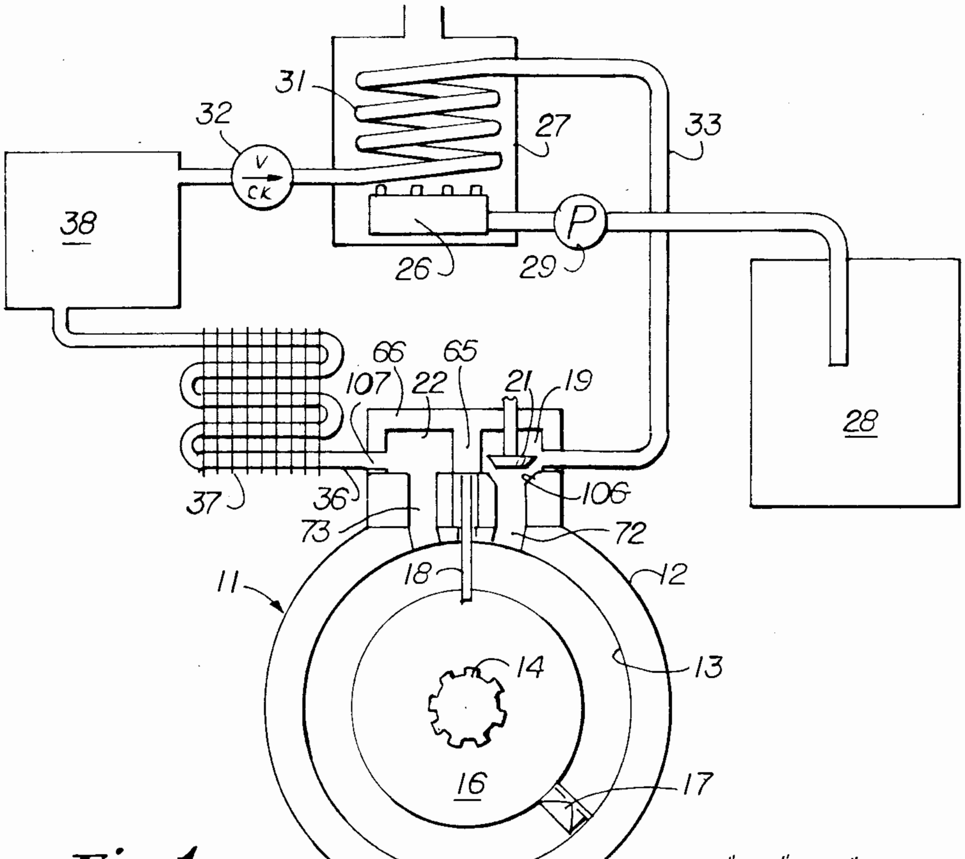


Fig. 1

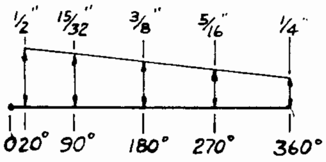


Fig. 8

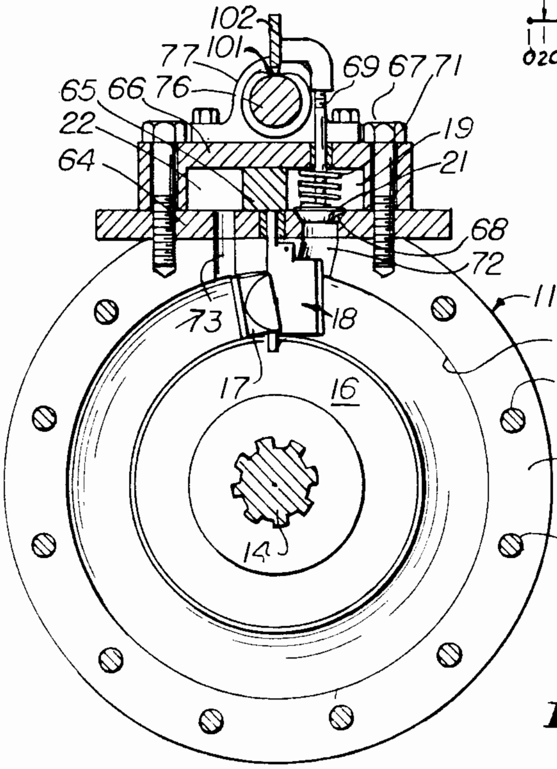


Fig. 4

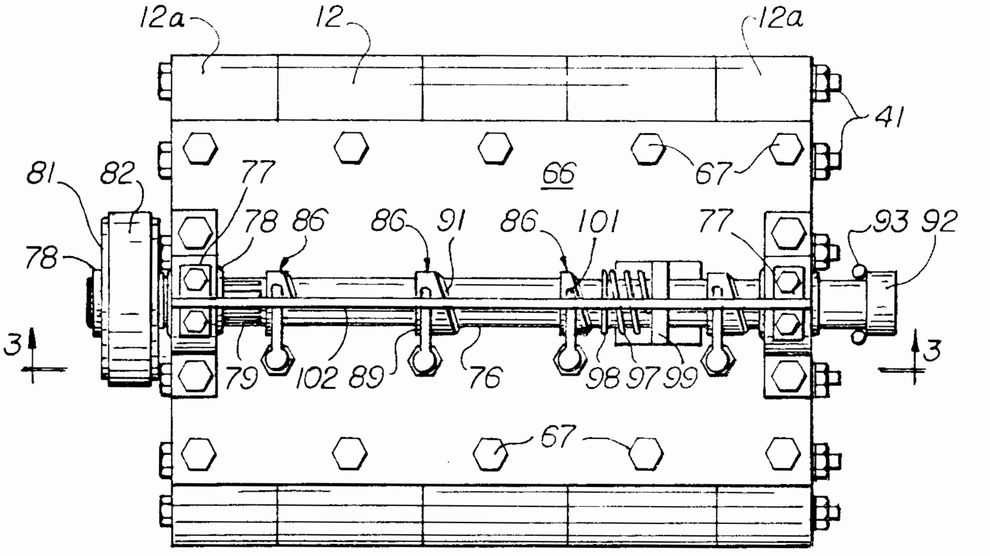


Fig. 2

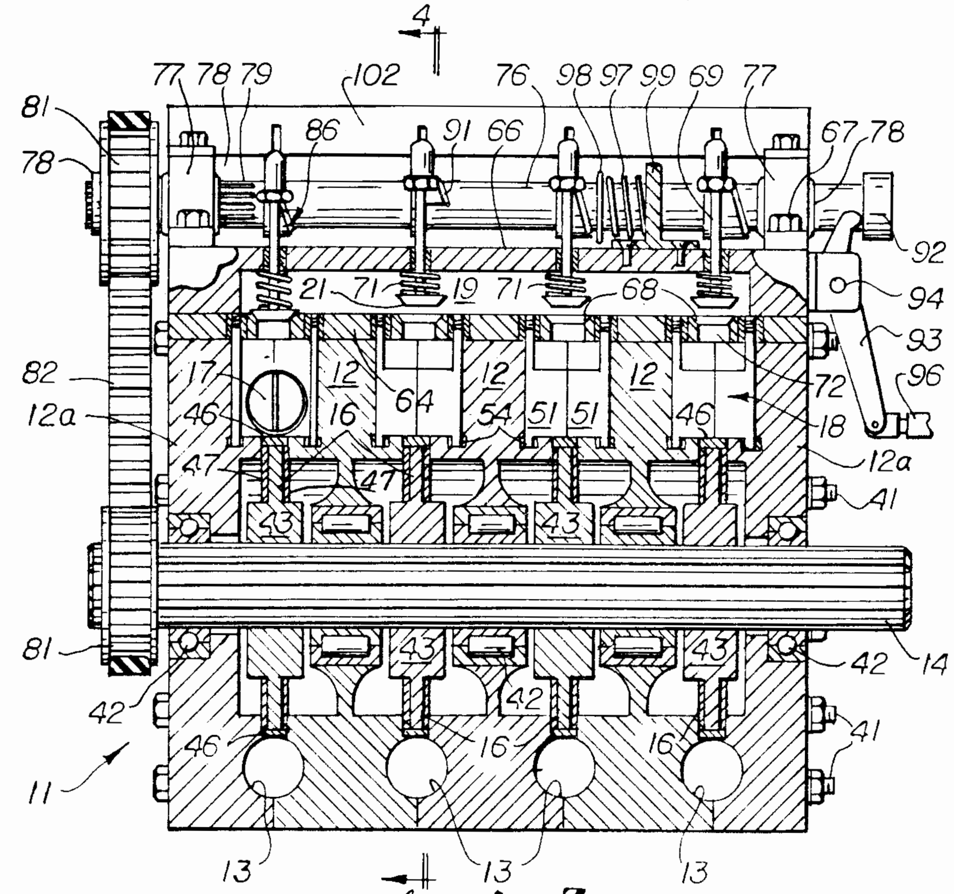


Fig. 3

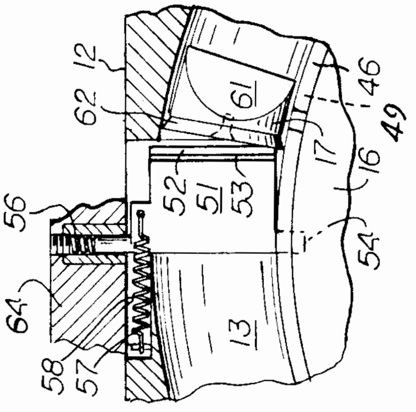


Fig. 7

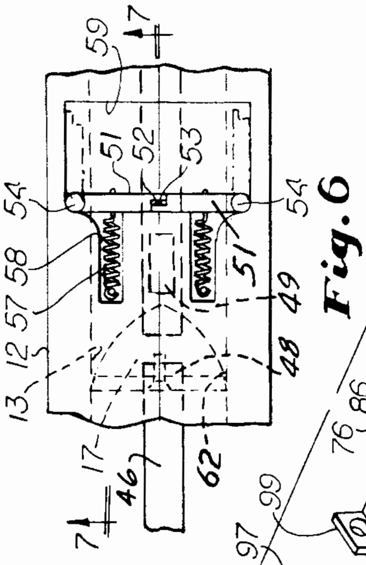
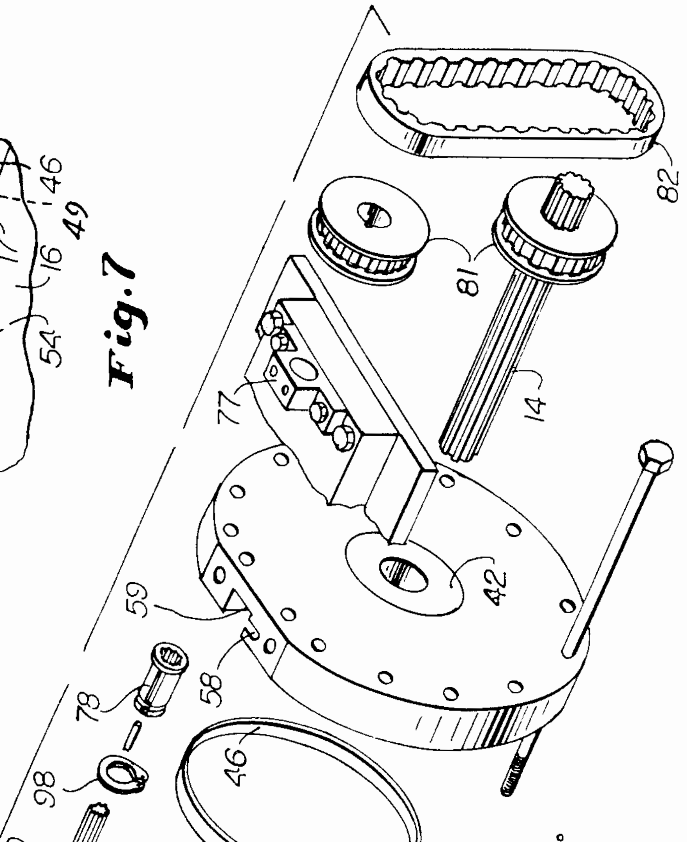


Fig. 6



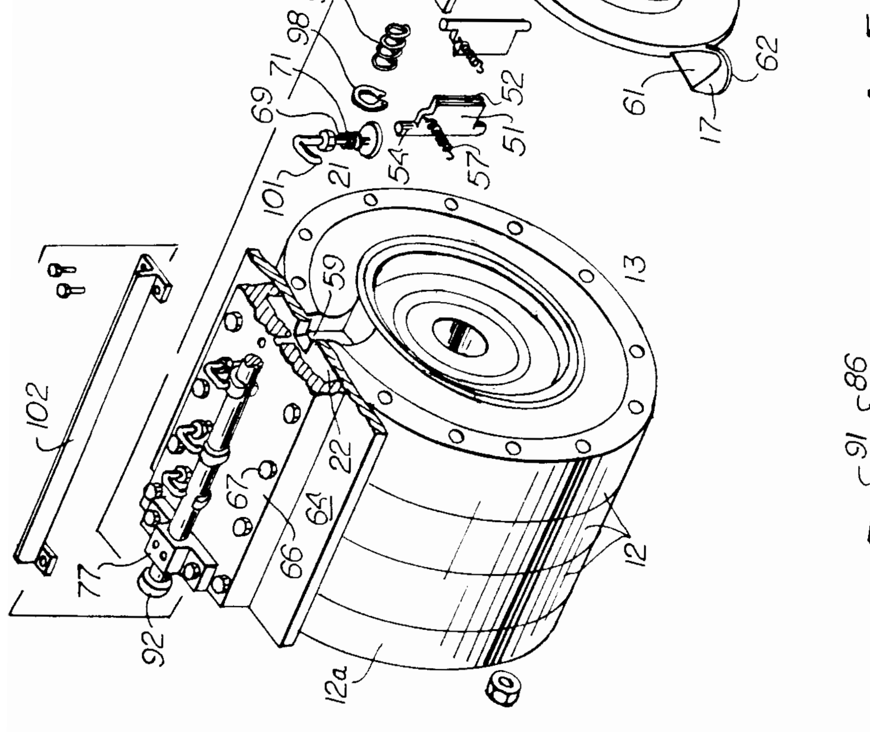


Fig. 5

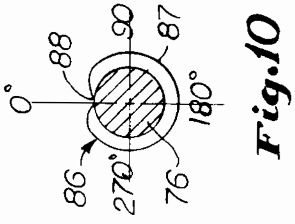


Fig. 10

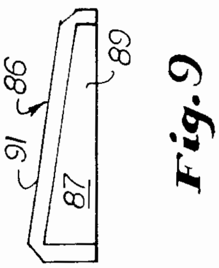


Fig. 9

ROTARY ENGINE WITH SEPARABLE ABUTMENT AND ADJUSTABLE VALVE CAM

This invention relates to a new and improved Stirling-type Rankine cycle rotary engine. In the preferred embodiment hereinafter described in detail, there are a plurality of toroidal cylinders formed in a series of engine blocks secured end-to-end, one-half of the torus being formed in each of two adjacent blocks. For each cylinder there is a piston which is attached to the outer periphery of a disk, the disk being fixed for rotation with the main shaft of the engine. The pressure of the medium which drives each piston may be applied for as much as 345° of rotation of the piston and thus the available force is applied on the end of the lever for substantially the entire rotation of the piston. This is one of the principal advantages of the present invention. At less than full power, the intake of gaseous medium into the cylinder behind the piston is cut off at any desired point thereby controlling the output of the engine. Further, one size engine can be controlled to accommodate a wide variety of loads.

A principal feature of the invention is the fact that it is simple in construction and has relatively few moving parts and is light in weight.

The thermal efficiency of the engine is very high, and all of the advantages of the Stirling-type Rankine cycle engine are achieved in the invention hereinafter described. Among these advantages are, in addition to the thermal efficiency, reduction in noise and of air pollution as compared with internal combustion engines. The fuel consumption is relatively low compared with conventional engines.

Still another feature of the invention is the fact that the engine and its parts are subject to less deterioration and wear because the heat is low as compared with internal combustion engines and the speed of rotation is also low.

When the engine is attached to an autoclave vehicle, it is not necessary to employ a transmission. The torque of the invention is the highest at stall.

A major feature of the engine is the fact that all the pressure in the cylinders can be converted to useful work on the main shaft, pressure being used down to line pressure at exhaust. The conventional four-cycle internal combustion engine wastes a substantial part of its pressure out the exhaust. This waste is greatly minimized in the present invention.

Other objects of the present invention will become apparent upon reading the following specification and referring to the accompanying drawings in which similar characters of reference represent corresponding parts in each of the several views.

In the drawings:

FIG. **1** is a schematic view showing the engine and its associated parts which make up the system.

FIG. **2** is a top plan.

FIG. **3** is a vertical sectional view taken substantially along the line **3—3** of FIG. **2**.

FIG. **4** is a transverse sectional view taken substantially along the line **4—4** of FIG. **3**.

FIG. **5** is an exploded perspective view with some of the parts being shown in different scale than other parts.

FIG. **6** is an enlarged fragmentary top plan view showing the main cylinder valves.

FIG. **7** is a fragmentary sectional view taken substantially along the line **7—7** of FIG. **6** and showing the piston at a different point in its cycle.

FIG. **8** is a theoretical development of a cam used to control the intake valve of the device.

FIG. **9** is a schematic projection onto a flat plane of the shape of the cam controlling the intake valve.

FIG. **10** is a schematic cross sectional view through the cam shaft.

Directing attention first to FIG. **1**, the engine **11** is shown schematically and only one of its multi-cylinders is shown. There is a block **12** formed with a semi-toroidal cylinder **13**. The block **12** mates with an adjoining block in which a similar semi-toroidal cylinder **13** has been formed so that when the two are assembled together there is a toroidal cylinder **13**. At the axis of the torus is main shaft **14**. Turning with the shaft **14** is a disk **16** carrying at its outer rim a piston **17** which, in its cycle of revolution travels around the cylinder **13**. At one point in the cycle there is a cylinder main valve **18**, hereinafter described in detail, which closes off the cylinder **13** to form two portions, one behind the piston **17** and the other ahead of same. The main valve **18** opens only when the piston **17** is passing therethrough and closes immediately thereafter. On one side of main valve **18** is intake manifold **19** controlled by valve **21**. When the valve **21** is opened, a gaseous medium under pressure is admitted to the cylinder **13**, driving the piston **17** forward (i.e., clockwise as viewed in FIG. **1**). On the side of main valve **18** opposite intake manifold **19** is an exhaust manifold **22** through which the medium in front of the piston **17** is continuously discharged.

An external burner casing **27** is provided and within the casing **27** is a burner **26** which may employ any available fuel. The fuel is stored in tank **28** and is directed to the burner **26** by pump **29**. Within the casing **27** is a coil **31** in which the gaseous medium is heated to increase its pressure and specific heat. Valve **32** prevents the backward flow of gaseous medium from the coil **31**. The exhaust gases flow out of manifold **22** through an exhaust conduit **36** to a condenser, cooler, or radiator **37** where the heat is reduced and the cooled medium is stored in a reservoir tank **38** for recirculation through the coil **31**.

The foregoing is a Stirling-cycle engine in that the heated gaseous medium drives a piston and the gaseous medium from the previous cycle of rotation is exhausted and condensed or at least cooled before being reheated and recycled. The combustion in burner **26** is external to the engine **11** and hence a more complete, efficient, pollution-free combustion is achieved. The gaseous medium may be of various gases and vapors including air, hydrogen, helium, steam, Freon, etc.

Directing attention now to the details of engine **11**, and with specific reference to FIGS. **2**, **3** and **4**, the engine block **12** intermediate to the ends of engine **11** are substantially identical and the two end blocks **12***a* are complementary. As is apparent from FIG. **3**, the semi-toroidal cylinders formed in each block and in each face of each intermediate block **12** are assembled side-by-side and held together by bolts **41** which pass through all of the blocks to form four cylinders **13**. It will be understood that one or more cylinders may be employed depending upon the desired capacity of the engine. Suitable bearings **42** in the blocks **12**, **12***a* support shaft **14** for rotation, the shaft **14** preferably being splined. Each disk **16** has a hub **43** which turns with the shaft **14**. On the outside of each disk **16** is a belt-shaped seal ring **46**. To complete the seal of belt **46**, a pair of annular belt seals or shoulders **47** is employed, the same being recessed into the blocks **12**, **12***a* immediately inside the belts **46**. The shoulders **47** are held in place by screws (not shown) or other means so that the shoulders **47** as well as the belts **46** may be replaced for wear as required.

The belt seal **46** turns with disk **16**, and for such purpose there is a substantially radial attachment **48** which secures the belt **46** to the piston **17**. A vent **49** is formed in the belt **46** to equalize the pressure when the main cylinder valve **18** is about to open so as to minimize the force of the main valve opening.

The main valve **18** is opened as the piston **17** passes there-through. Various means may be used to time the opening of main valve **18** but a simple means is herein illustrated. In this embodiment, it is the motion of the piston **17** itself which opens the main valve. For this purpose, the valve **18** consists of two gate members **51** which are pivoted for opposite movement in the blocks **12** or **12***a*. The inner edges of gates **51** are formed with rabbets **52** so that they overlap and there is a gate seal **53** along one or both of the rabbetts **52**. The gates **51** pivot on pintles **54** at the top and bottom, being rotatably mounted in the blocks **12**, **12***a*. A helical spring **56** biases the upper pintles **54** downwardly to keep the lower edges of the gates **51** in contact with the belt seal **46** and walls of cylinders **13**. Return springs **57** hold the gates **51** closed, said springs **57** being received in recesses **58**. The blocks **12**, **12***a* are formed with openings **59** to permit the gates to swing open from solid line to dotted line position, as best shown in FIG. **6**. The forward nose **61** of piston **17** is round and the piston is provided with a chevron seal **62**. The nose **61** of the piston pushes the gates open and the springs **57** return same to closed position.

The tops of the blocks **12**, **12***a* are formed with horizontal flats to which is bolted a valve plate **64** extending across all of the blocks. Above plate **64** is a valve chest **66** in which the intake and exhaust manifolds **19**, **22** are formed with partition **65** therebetween. Bolts **67** hold down the chest **66**. In plate **64** are valve seats **68**. The valve stems **69** extend upward from valves **21** and are biased to seat on the seats **68** by valve springs **71** surrounding the stems **69** and bearing against the underside of chest **66**. Thus there is an inlet port **72** between inlet valve seat **68** and cylinder **13** to one side of the main cylinder valve **18** and an exhaust port **73** communicating from the cylinder **13** to the exhaust manifold **22**.

Rotatable in timed relation to shaft **14** is a cam shaft **76** mounted by means of pillow blocks **77** and sleeves **78** on shaft **76** and bolted to the top of chest **66**. The left-hand end of shaft **76** (as viewed in FIGS. **2** and **3**) is formed with a splined section **79**. Pulleys **81** are mounted on shafts **76** and **14** and interconnected by a belt **82**. Upper pulley **81** is fixed to sleeve **78** by a key on other means.

For each of the cylinders **13** there is a cam **86** mounted on shaft **76** and the location of the cam **86** determines the timing of the various cylinders which is preferably a 1-3-4-2 cycle. The development of each cam is best shown in FIGS. **9** and **10**. In the form of cam shown in FIG. **10** there is a high dwell **87** which extends around most of the circumference of cam shaft **76** and a low dwell **88** for about 20°. The low dwell **88** insures that the valve **21** is closed as the piston **17** passes through the cylinder main valve **18**. As best shown in FIG. **9**, one edge **89** of the cam high dwell **86** is straight while the other edge **91** is slanted and beveled. As hereinafter appears, the cams **86** are movable axially with the shaft **76** and the position which they have at any instant determines how long the valve **21** is opened.

To move the cams **86** (and their shaft **76**) axially, one end of shaft **76** is formed with a collar **92** against which bears a clevis type lever **93** mounted in bracket **94** on one of the end blocks **12***a*. Rod **96** extends to a hand or foot control which governs the speed of the engine. By pushing the rod **96** to the left, as viewed in FIGS. **2** and **3**, the shaft **76** is pulled to the right, pulling the cams **86** therewith. The shaft **76** is returned by means of return spring **97** which surrounds the shaft **76**. One end of the spring **97** bears on a collar **98** attached to shaft **76** and the other bears against a stationary abutment **99** fixed to chest **66**.

For each valve **21** there is a cam follower **101** attached to the upper end of valve stem **69**. The follower **101** is held in place by a hold-down **102** bolted to pillow blocks **77**. Thus the follower **101** follows the high and low dwells of cams **86**. As viewed in FIGS. **2** and **3**, the farther the shaft **76** is to the right, the longer the followers **101** are in engagement with the high dwell **87** of the cams and the longer the valves **21** are opened. Thus by means of rod **96** the engine is controlled in the sense that gaseous fluid is admitted to each cylinder **13** behind piston **17** for a short or longer portion of the cycle of rotation of the piston depending upon the portion of the cycle when follower **101** is in engagement with the high dwell **87** of cam **86**.

OPERATION

A gaseous medium is installed in the lines and cavities of the system up to hundreds of atmospheres pressure. Then burner **26** is ignited and heats the gaseous medium in coil **31** causing the multiplied pressure of the medium to pass to the intake manifold **19** thru intake port **72** and thence for a portion of the cycle of rotation of the engine into the cylinder **13**, driving the piston **17** before it and thus causing the disk **16** to rotate the shaft **14**. The main valve **18** is, of course, closed during all of the power stroke of the piston **17**. The spent gases from the previous cycle are discharged through exhaust port **73** into manifold **22** and thence to cooler or condenser **37** where the gas is cooled and condensed and returned to supply tank **38** to begin another cycle.

As the piston **17** passes through the main valve **18**, it swings the gates **51** in FIG. **5** about their pintles **54** to open position; but as soon as the piston **17** has passed the main valve **18**, the springs **57** return the gates **51** to closed position. It will be understood that the gates **51** may be controlled by other means.

Speed control is achieved manually or pedally by moving the rod **96** in FIG. **3** causing the clevis lever **93** to move the shaft **76** to the right and the spring **97** to return it toward the left. Depending upon the position of shaft **76**, the cam follower **101** comes into engagement with the high dwell of the cam **86** and more particularly its slanted edge **91** and this raises the valve **21** against the force of spring **71** which tends to return it. When the follower **101** engages the low dwell **88**, the valve **21** is closed. The valve **21** is always closed as the piston **17** passes through the main valve **18**. Further, to equalize pressure on both sides of main valve **18**, the pressure in cylinder **13** leaks through vent **49** in seal **46**, going under main valve **18** to exhaust port **73** as viewed in FIGS. **4** and **5**.

What is claimed is:

1. An engine comprising means forming a toroidal cylinder, a main shaft at the axis of said cylinder, a piston rotatable in said cylinder, means for turning said piston and main shaft together, a main valve in said cylinder, an intake port on one side of said main valve, an outlet port on the side of said main valve opposite said intake port and means for supplying gas under pressure to said intake port, an intake valve controlling said means for supplying gas, a cam shaft having a cam, means rotatably mounting said cam shaft on said engine for axial movement and rotative movement, means driving said cam shaft in time relation to said main shaft, means for adjusting the longitudinal position of said cam shaft, a cam follower, means articulately connecting said cam follower to said intake valve, each said cam having a high dwell with a ramp configuration such that the extent of opening of said intake vavle varies in an axial direction, whereby as said cam shaft is moved longitudinally the duration of opening of said inlet valve is adjusted.

2. An engine comprising a block formed with a toroidal cylinder, a main shaft rotatable at the axis of said cylinder, a disk-like member fixed for rotation with said main shaft, a piston on the periphery of said disk-like member rotatable about said cylinder, said block formed with a slot for passage of said disk-like member, seal means sealing said cylinder against leakage through said slot, a main valve in said cylinder, actuating means to permit opening of said main vavle for passage of said piston therethrough and to close said main valve after passage of said piston, means forming an inlet port to said cylinder on a first side of said main valve, means forming an outlet port to said cylinder on a second side of said main valve opposite said first side, means supplying gas under pressure to said inlet port, an intake valve controlling admission of said gas to said cylinder behind said piston to drive said piston around said cylinder, a cam shaft driven in timed relation to said main shaft, a cam on said shaft, a cam follower, means articulately connecting said cam follower and said intake valve, said cam having a high dwell with a ramp configuration and means for relatively moving said ramp configuration and said cam follower to time the duration of opening of said intake valve, said ramp configuration being such that the extent of the high dwell varies in an axial direction so that said follower is lifted varying time intervals as said ramp is moved axially relative to the follower.

3. An engine comprising a block formed with a toroidal cylinder, a main shaft rotatable at the axis of said cylinder, a disk-like member fixed for rotation with said main shaft, a piston on the periphery of said disk-like member rotatable about said cylinder, said block formed with a slot for passage of said disk-like member, seal means sealing said cylinder against leakage through said slot, a main valve in said cylinder, actuating means to permit opening of said main valve for passage of said piston therethrough and to close said main valve after passage of said piston, means forming an inlet port to said cylinder on a first side of said main valve, means forming an outlet port to said cylinder on a second side of said main valve opposite said first side, means supplying gas under pressure to said inlet port, and an intake valve controlling admission of said gas to said cylinder behind said piston to drive said piston around said cylinder, said seal means comprising a belt fixed to said disk-like member on the periphery of said disk-like member, said belt being wider than the thickness of said disk-like member, said block being recessed for movement of said belt, and disk-like replaceable belt shoulders fixed non rotatively to said block immediately inside said belt, one on each side of said disk-like member, said belt sealing against said shoulders.

4. An engine according to claim **3** in which said belt is formed with a vent under said piston to equalize pressure before said piston passes through said main valve.

5. An engine comprising a block formed with a toroidal cylinder, a main shaft rotatable at the axis of said cylinder, a disk-like member fixed for rotation with said main shaft, a piston on the periphery of said disk-like member rotatable about said cylinder, said block formed with a slot for passage of said disk-like member, seal means sealing said cylinder against leakage through said slot, a pair of gates having pintles at top and bottom of a first edge of each said gate, first resilient means biasing said gates to closed position extending transversely of said cylinder, second edges of said gates opposite said first edges in closed position meeting in the center of said cylinder to close off gas flow through said main valve, means forming an inlet port to said cylinder on a first side of said main valve, means forming an outlet port to said cylinder on a second side of said main valve opposite said first side, means supplying gas under pressure to said inlet port, an intake valve controlling admission of said gas to said cylinder behind said piston to drive said piston around said cylinder, a valve chest fixed to the exterior of said block vicinal said main valve and having an inlet and an outlet manifold communicating with said inlet and outlet ports respectively, a valve seat formed in said valve chest, said intake valve seating on said valve seat, one said pintle being journaled in said valve chest, second resilient means biasing said gates away from said valve chest and against the wall of said cylinder opposite said valve chest to seal said cylinder at said main valve, said piston having a wedge-shaped nose shaped to force said gates open upon contact of said nose with said gates.

* * * * *

***DeVaux* POWER FMCA**
Zero-Pollution Internal Combustion Engines

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The DeVaux Engine is basically a scotch yoke mechanism to convert expanding energy, no matter from what source into mechanical motion to perform work. We prefer to call it a "one stroke cycle" engine. All four elements required for internal combustion are accounted for in one stroke. For example, unlike the others, the DeVaux has no crankshaft. It has only a crank with a pin on each side at 180° to engage one of only two rods. The trick is that each of the three articulating parts serve more than one function. In a conventional engine each part can accomplish only a single function, hence very low efficiency. The engine runs on "super combustion," more commonly called detonation. The exhaust carries NO hydrocarbons and NO nitrous oxides and zero to $^3/_4$ of a percent CO. The exhaust gas temperature on gasoline is at just ~~under 500°. The~~ exhaust contains considerable amounts of oxygen and hydrogen and there is little or no change to the exhaust on any fuel from diesel to the lowest BTU content fuel. At every 180° two cylinders fire giving over 400° of mean effective leverage on the crank equaled only by an eight cylinder 4 cycle engine while having only half the weight. Exhaust analysis was performed at Marquardt Corp. recognized by NASA.

DeVaux Power was founded in October 1995 to develop and commercialize breakthrough zero pollution combustion technology. DV is implementing a strategy of global licensing and strategic partnering with major manufacturers and end-users in order to make the technology available as quickly, widely and inexpensively as possible.

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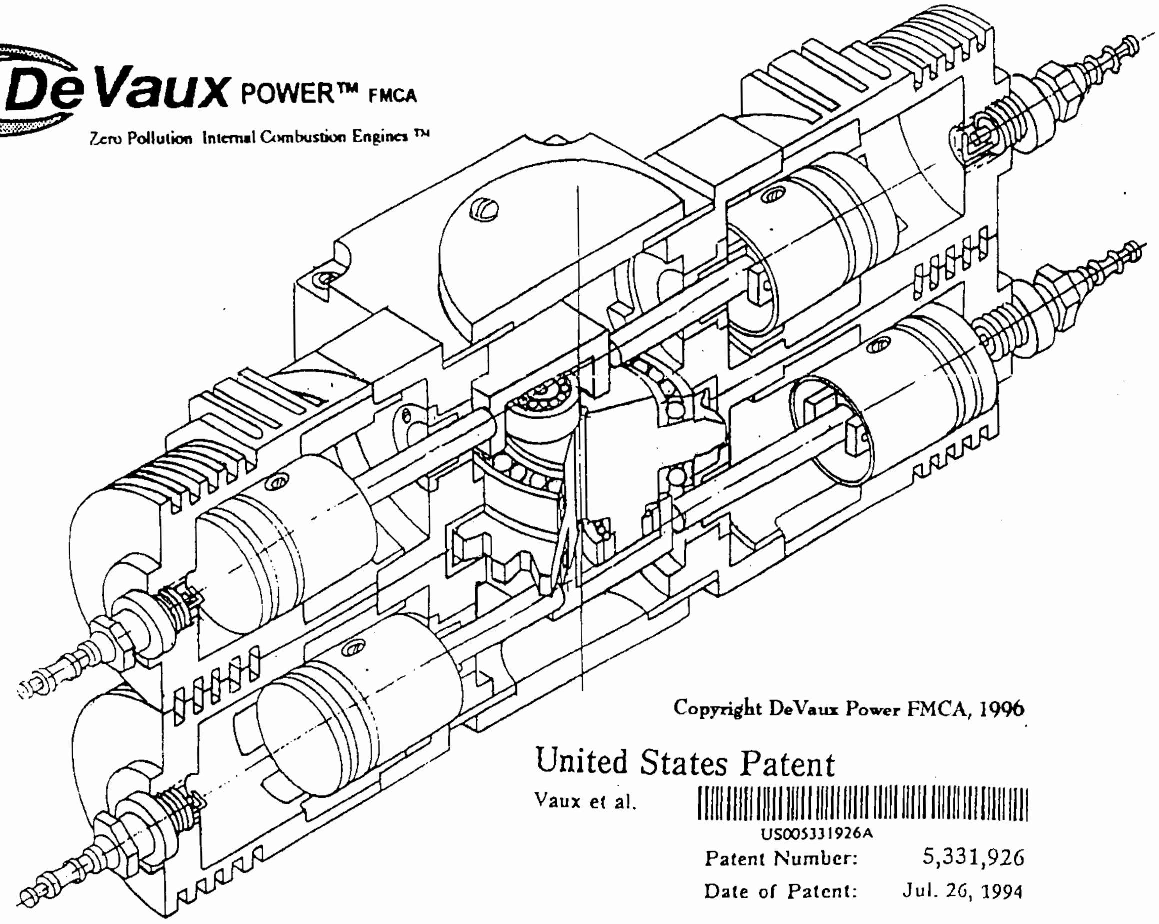

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United States Patent
Vaux et al.
US005331926A
Patent Number: 5,331,926
Date of Patent: Jul. 26, 1994

the pressure and leverage on the crank is more than doubled leading to lower fuel consumption. This is the pint which racing engine design people are missing without realizing it. When the point of detonation or 'super combustion' is reached it is over for conventional engines.

- The efficiency rate at present is calculated taking into consideration only oscillating rod engines.
- The very low EGT (exhaust gas temperature) using gasoline just under 500° F to slightly over 800° F depending on the fuel shows it is converting more, if not all the fuel. NO H-C left over.

ADDENDUM

1. It is important to review our testing history. We've had several prototypes running for a number of years from 20 cu. in. to 450 cu. in. in 4 cylinder units. At first, before doing expensive laboratory independent testing we did our own testing to be sure and to verify our own cursory and sensory observations. Among these was the very obvious fact of very low exhaust temperature (very difficult to notice) and the change in exhaust odors. First, we measured the water content in the exhaust. This is quite easy using a copper tube coil immersed in ice water. Same as an alcohol still. And low and behold nearly 15% water instead of the usual close to 85% on gasoline. This told us that there was a major shift in exhaust chemistry.

2. Our DeVaux engine was set up to run side by side in direct comparison with a Minneapolis Moline industrial diesel to pump water. Both engines were very close to equal cu. in. displacement. Each engine was set up to use natural gas. This is a fuel commonly used in farming country. Both pumps were adjusted to run at the same RPM thereby pumping equal volume per minute. Each unit (engine/pump) ran five weeks 24 hrs. a day non-stop. The DeVaux fuel consumption was 40% of what the industrial engine used.

EXHAUST ANALYSIS

Tests were conducted at Kaiser Marquardt, Inc. (a division of Kaiser Aerospace), Van Nuys. California.

Fuels Tested: Unleaded, Regular and Propane

CRITICAL PARAMETERS	PERCENTAGE/RESULT
Unburned Hydrocarbons	0 ppm
Nitric Oxides (Nox)	0 ppm
Carbon Monoxide (CO)	0 to .8%
Free Oxygen	8 - 11%
Water (H20)	12 - 16%
Port EGT (Exhaust Gas Temp)	477 - 819 F.

All conventional engines produce approximately 85% water. Their port EGT is always 1800 F.

Appendix I.

DV Engine Emissions Test Results

We have four running prototypes not just suggestions or ideas. We have done exhaust analysis and fuel consumption testing under continuous load for up to 840 hrs. non stop. Exhaust results appear to have little if any relation to engine size ei., bore and stroke.

PORT EGT (EXHAUST GAS TEMPERATURE) ranged between 477° F to 680° F on gasoline and 763° F to 819° F on propane. These temperatures are very low compared to conventional spark ignition engines which is always around 1800° F.

H20 (WATER) The test shows that water averages 14% to 16% excepting the fourth run which was 20% on propane. The low percentage of water is unprecedented for any engine.

Conventional engines produce 85% water. Low water proves that our unique chemistry is valid in that free oxygen and HYDROGEN are produced. In other words, oxygen and hydrogen are not going back to water but are remaining in their elemental state, uncombined to undesirable hydrocarbon compounds.

NOX (NITROUS OXIDES) All runs show no nitrous oxides. This is another unprecedented result.

HYDROCARBONS are non-existent in all runs except #4. This run was interesting as it was rich on fuel and produced some hydrocarbons and more water than the other runs. There was no carbon monoxide, therefore, the extra oxygen went to water rather than the oxide of carbon, CO. This further demonstrates the validity of the chemistry.

FREE OXYGEN was measured at 8% to 11%.

FREE HYDROGEN is also present although this was not measured. However, by calculation, hydrogen is present due to the very low water and no hydrocarbons. It can be calculated directly.

- Test equipment accuracy - ½ part per million. Item 9; Total **C-H**, indicates unburned hydrocarbons. Item 5; Nitrous Oxide is NOX. No other engine can disassociate this compound.

- The ability to run the engine on full blown detonation without destruction revealing a completely new chemistry of combustion heretofore undreamed of because no engine could replicate detonation.

- The straight rod will not bend, break or fold during detonation.

- The opposing piston at each end of the rod serves to cushion each reaction or firing. Piston #1 and #3 fire at the same time. Then #2 and #4 fire together doubling the mean effective leverage on the crank without adding more cylinders. The only logical conclusion is that over 400° of leverage is delivered to the crank in one revolution.

- Therefore the engine **cannot** destroy its self because all loads are towards the crank not away from it nor to the side. The engine can run at maximum constant RPM, no damage like an electric motor.

- However, unlike an electric motor it exhibits a very wide torque range approximating 1000 RPM as opposed to only 50 for electric motors, 500 for conventional diesels and not much beyond 750 for gasoline engines and does so at a much lower RPM. Much more tractable for any application trucking, heavy equipment, autos, boats etc.

- The engine has a very low, compact silhouette due to being a flat four and weighs about one half that of an equal displacement conventional engine.

- Returning to the patent drawing again, you will see the rod has an involute cam ground into it which allows piston timing at or near TDC. This means the piston can dwell at or near TDC as required. Very important, WHY?.... Therefore the patent title "Dwelling Scotch Yoke engine."

- Piston speed cannot exceed the rate of burn and when two cylinders are fired simultaneously

US005331926A

United States Patent [19]

Vaux et al.

[11] **Patent Number: 5,331,926**

[45] **Date of Patent: Jul. 26, 1994**

[54] **DWELLING SCOTCH YOKE ENGINE**

[75] Inventors: **Melvin A. Vaux**, Kingman, Ariz.; **Thomas R. Denner**, Clark County, Nev.

[73] Assignee: **Denner, Inc.**, Las Vegas, Nev.

[21] Appl. No.: **96,790**

[22] Filed: **Jul. 23, 1993**

[51] **Int. Cl.**^{5} **F02B 75/24**

[52] **U.S. Cl.** .... **123/56 BC**; 123/56 C; 123/196 R; 123/197.4

[58] **Field of Search** .... 123/197.3, 197.4, 56 R, 123/56 B, 56 BC, 56 C, 196 R

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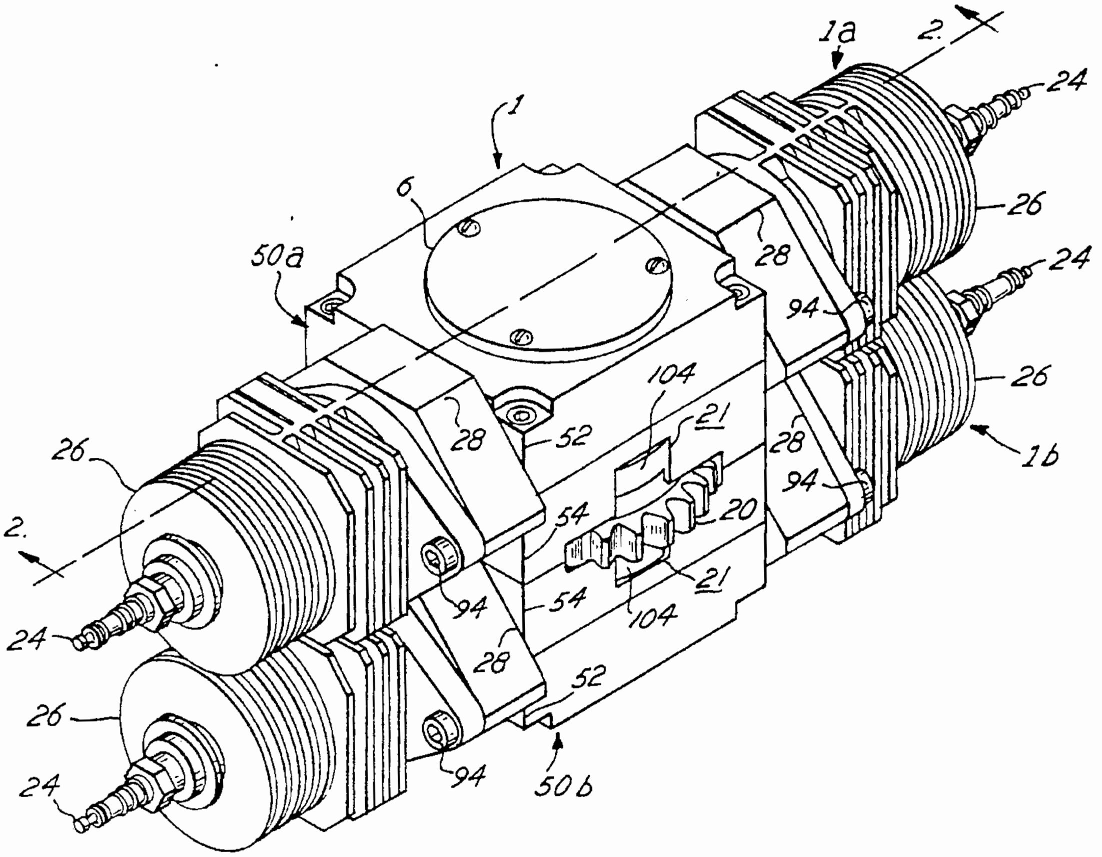
Primary Examiner—Noah P. Kamen
Attorney, Agent, or Firm—James D. Hall

[57] **ABSTRACT**

An improved engine utilizing a dwelling scotch yoke and a journalled flywheel in a unique combination for stalling the translatory movement of oppositely paired pistons during the detonation of the fuel mixture to achieve a clean exhaust and a energy efficient engine.

18 Claims, 7 Drawing Sheets



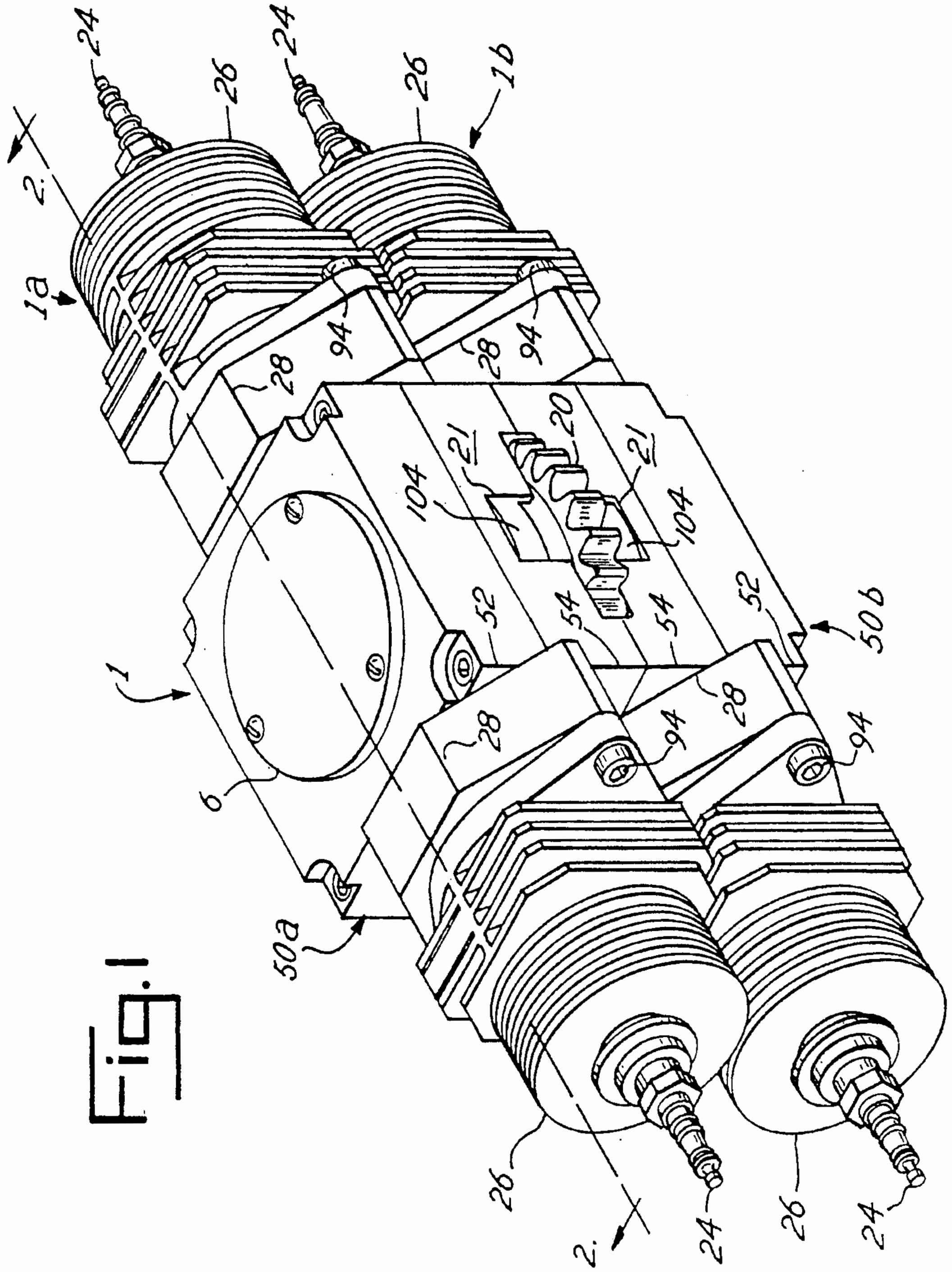

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Fig. 1

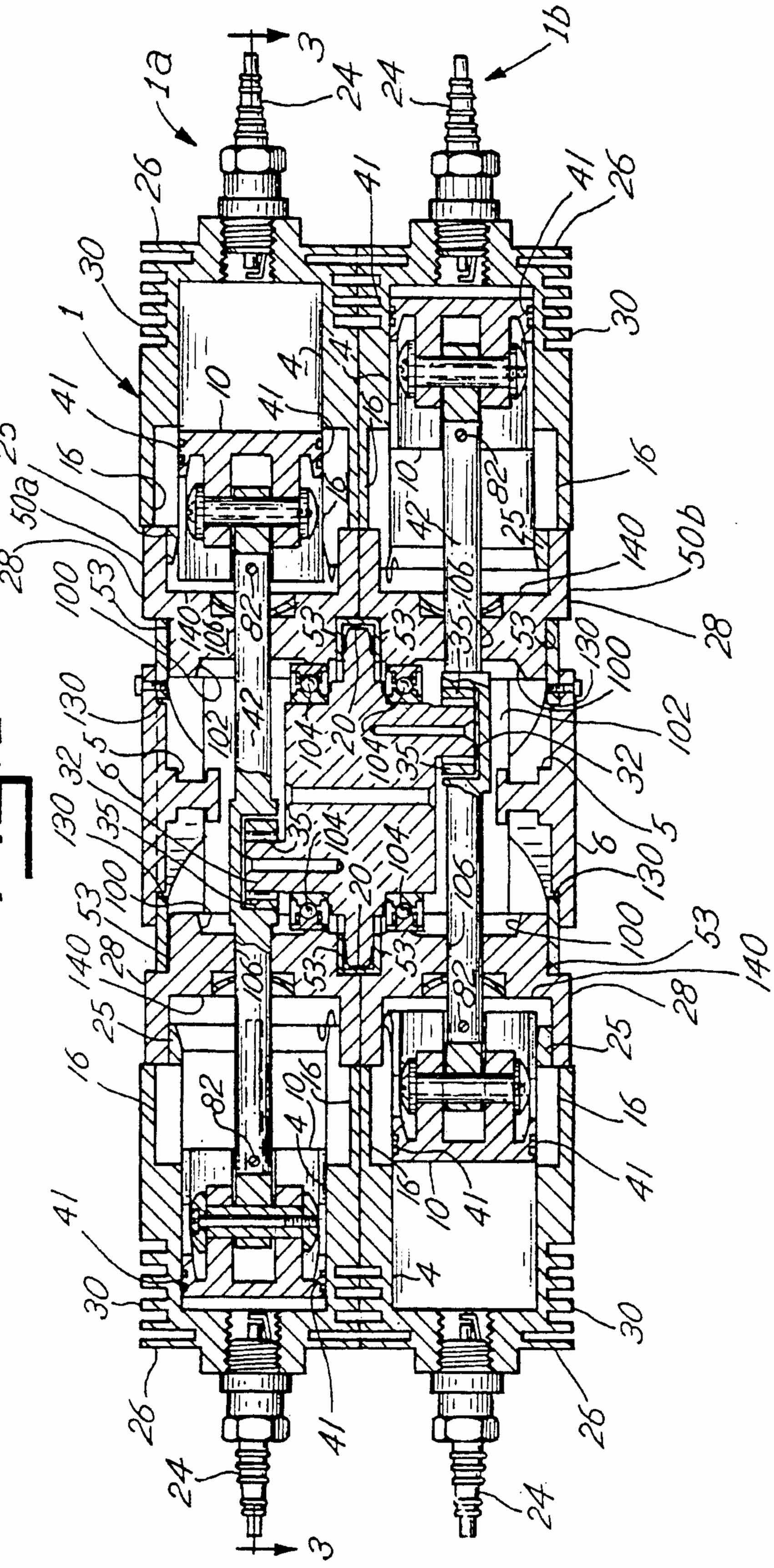
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Fig. 2

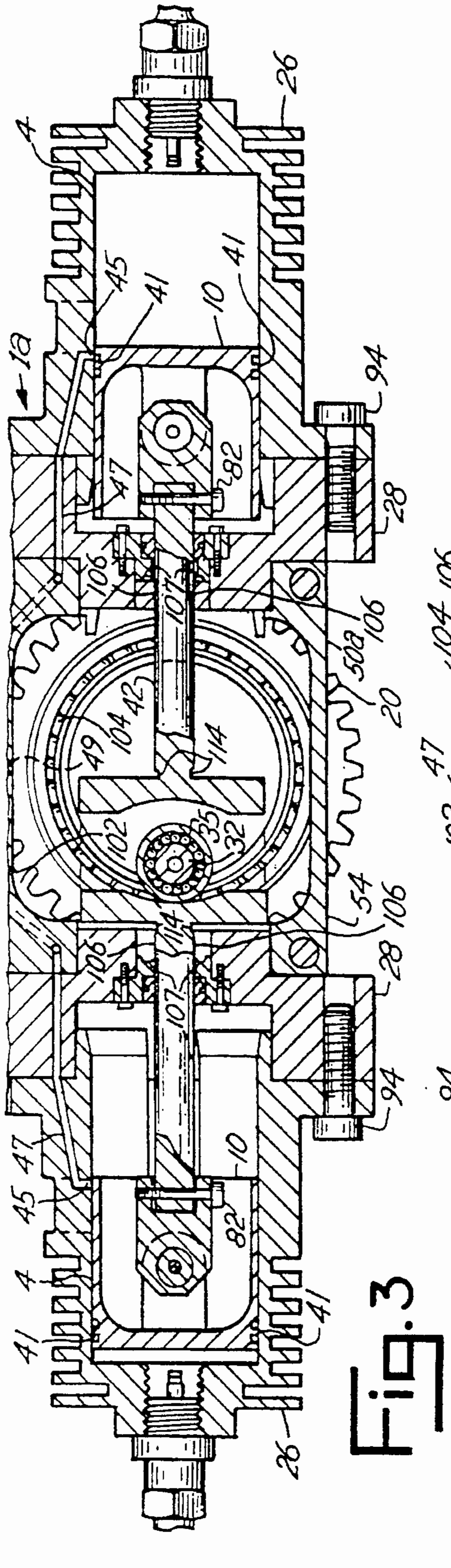
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Fig. 3

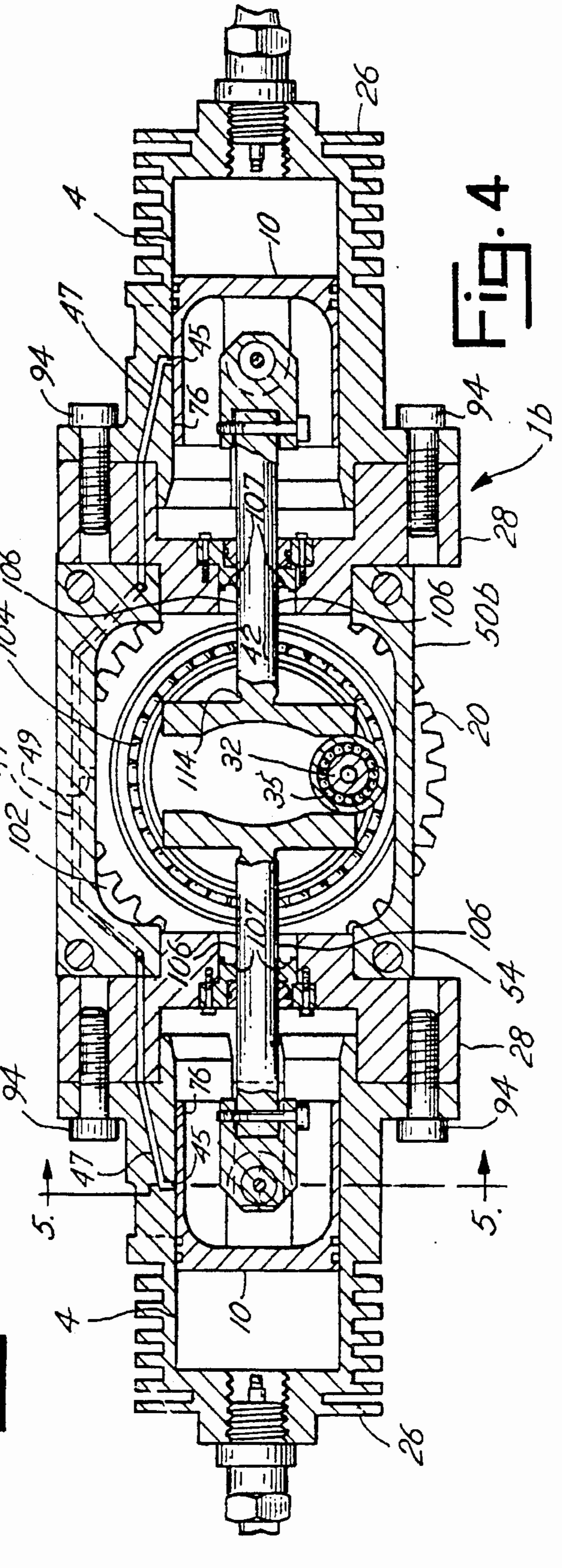
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Fig. 4

Fig.5

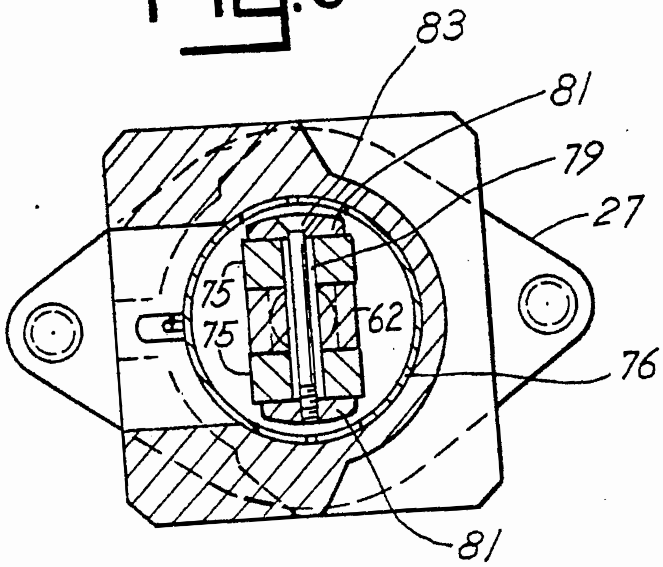


Fig.6

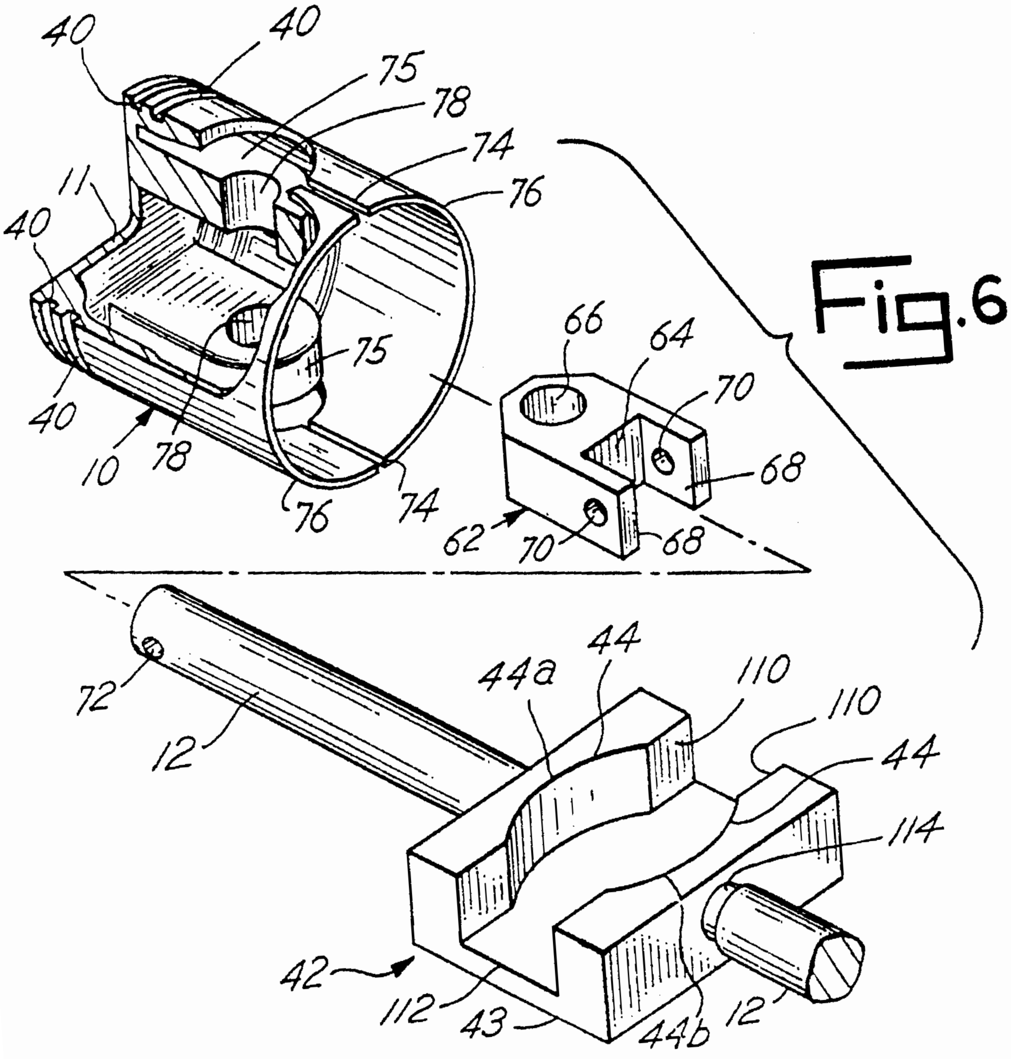


Fig.7

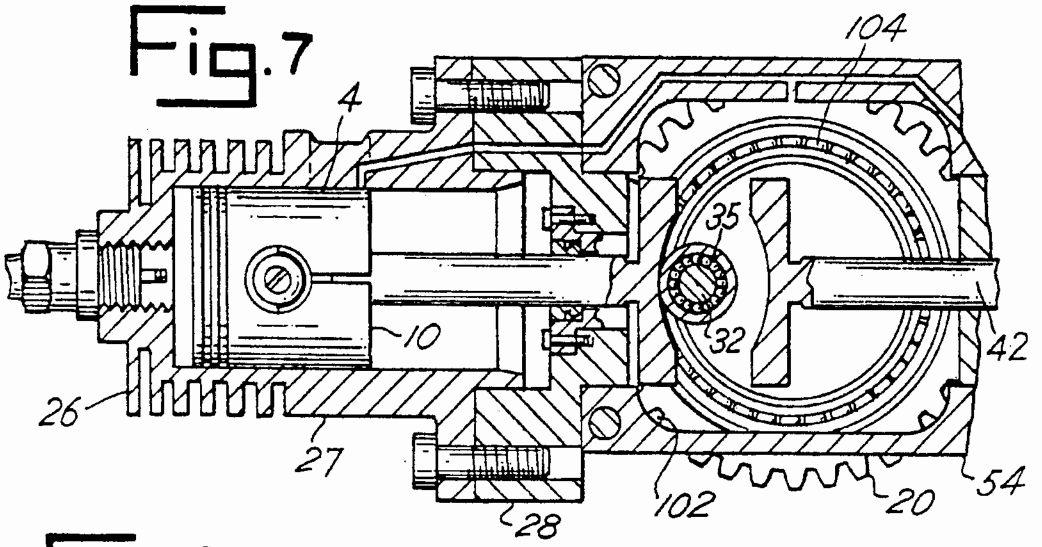


Fig.8

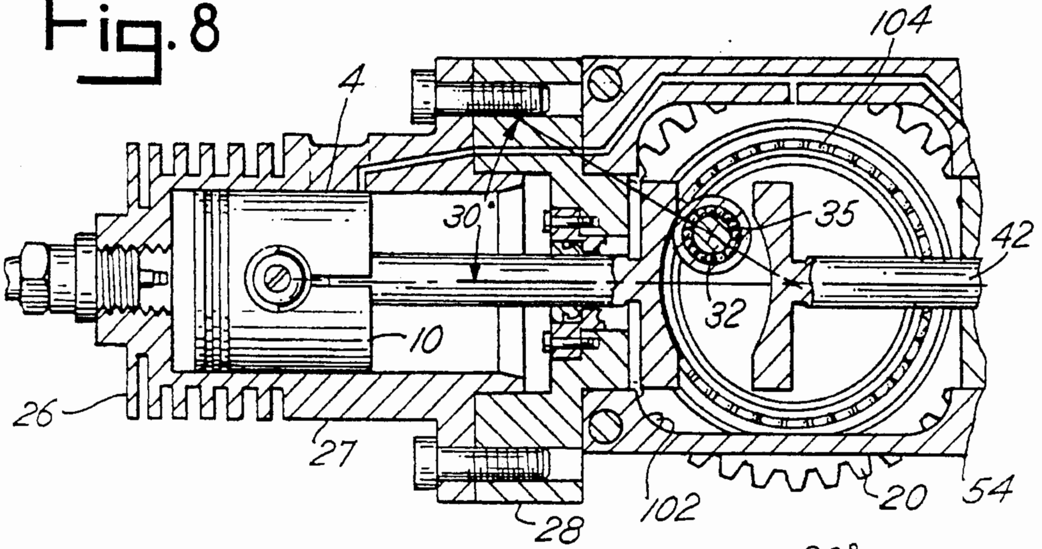


Fig.9

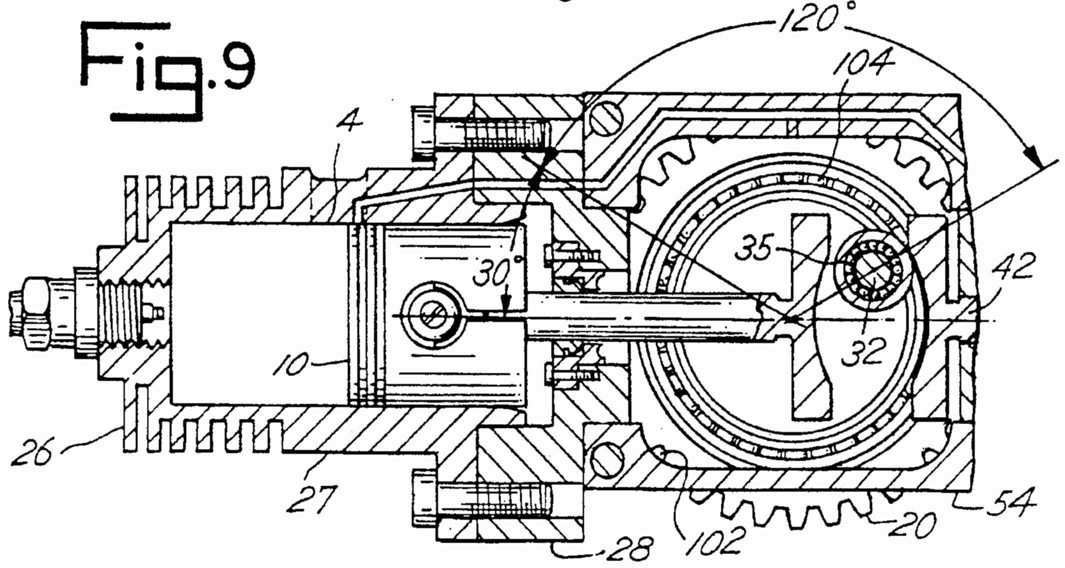


Fig.10

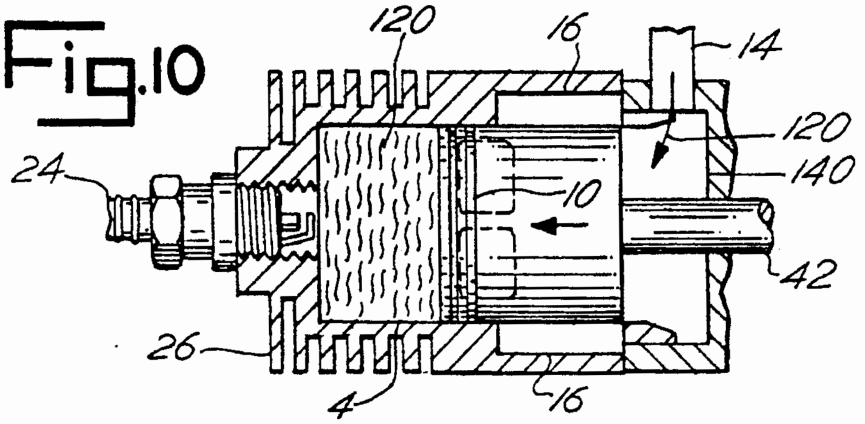


Fig.11

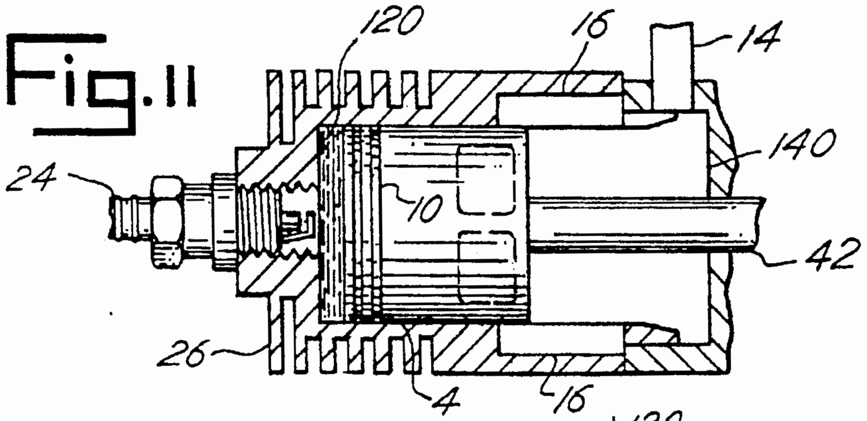


Fig.12

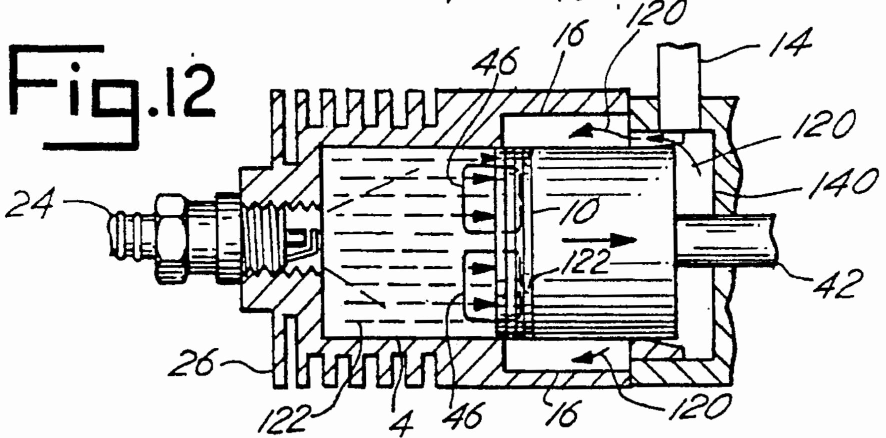


Fig.13

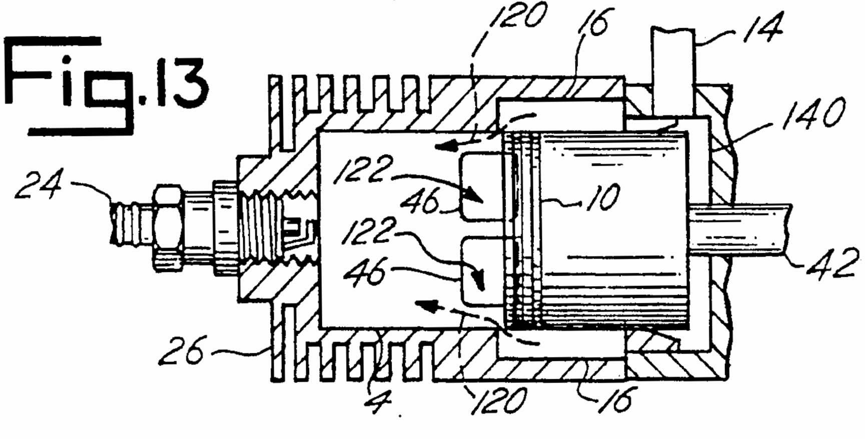
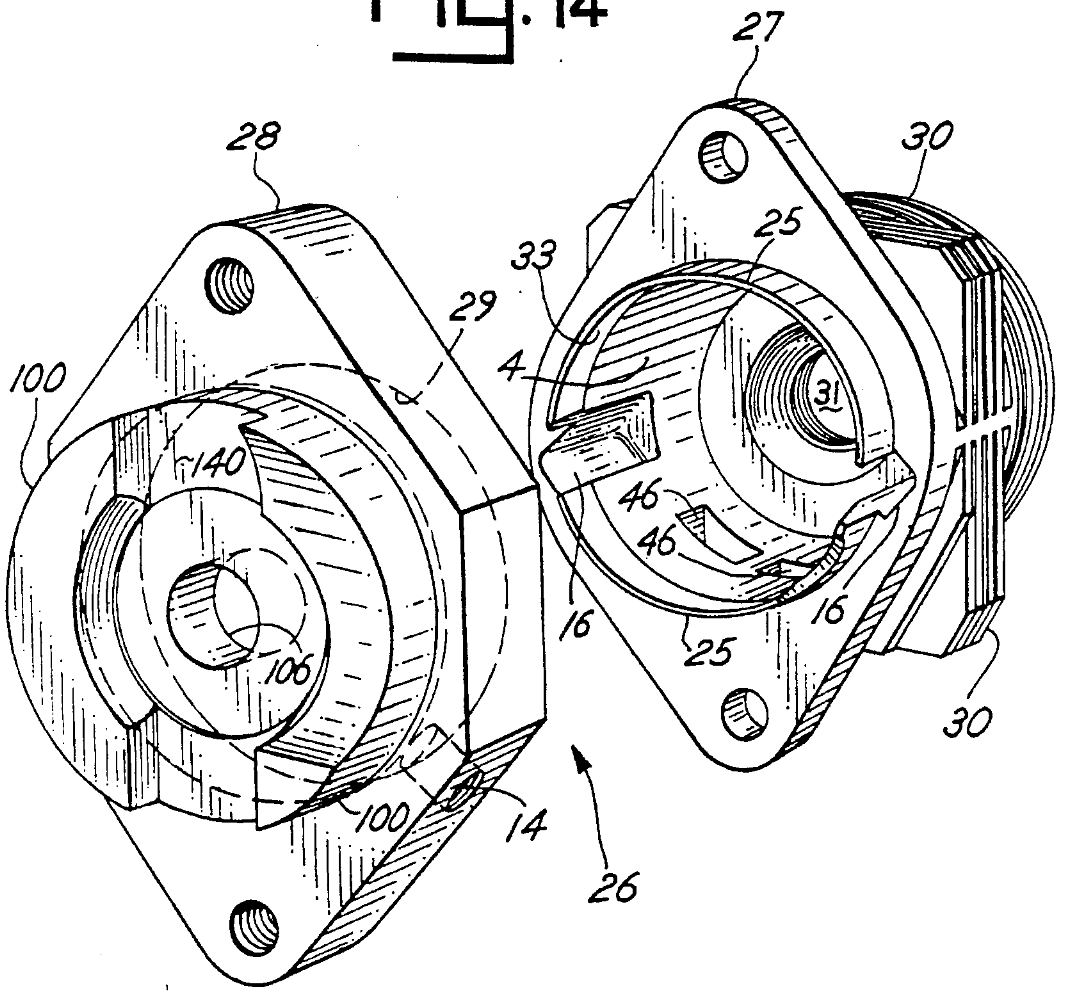


Fig. 14



DWELLING SCOTCH YOKE ENGINE

SUMMARY OF THE INVENTION

This invention relates to an improved engine, and will have special application, but not necessarily so limited, to internal combustion engines which can be used in lawn mowers to diesel electricity generators.

The engine embodied in this invention utilizes a dwelling scotch yoke and a journalled flywheel in a unique combination for stalling the translatory movement of oppositely paired pistons during the detonation of lean fuel mixture. A fixed volume is thus maintained above the piston during detonation, in which a complete chemical reaction of the fuel molecules and the rich air can occur. Consequently, the fuel mixture can be disassociated into its purer elements to achieve a very clean exhaust and a highly energy efficient engine.

An additional feature of this engine is that it is compact and efficient in size and maintenance. The journalled flywheel obviates the use of a crankshaft and throws typically used in two and four cylinder engines. Further, the flywheel functions as an oil pump for supplying lubrication to the pistons. Each of the pistons have flared skirts to allow for better engine lubrication and to reduce heat warping, thus reducing wear.

The engine also utilizes cylinders with sealed end walls. The cylinder bore by being enclosed at its lower end is separated from the crankcase internal chamber where the journalled flywheel and oil bath is located. The presence of the cylinder end wall functions to provide a barrier between the cylinder bore and the oil bath and also to allow for an increase in the density of the fuel mixture during piston movement. By increasing the density of the fuel mixture, it is more efficiently burned during the detonation process.

Still another feature of the cylinder is the location and size of its exhaust ports. The exhaust ports are located such that the exhaust gases generated within the cylinder are not released until the piston completes its inward or power stroke. Thus, a longer power stroke is achieved resulting in increased horsepower than can be gained using conventional cylinders.

Accordingly, an object of this invention is to provide an energy efficient engine.

Another object of this invention is to provide an engine that produces environmentally favorable exhaust.

Still another object of this invention is to provide an engine that can operate by burning various forms of fuels.

Still another object is to provide an engine that is compact, lightweight, durable, easily assembled, and economical.

Other objects will become apparent upon a reading of the following description.

BRIEF DESCRIPTION OF THE DRAWINGS

A preferred embodiment of the invention has been depicted for illustrative purposes only wherein:

FIG. 1 is a perspective view of the invention.

FIG. 2 is a longitudinal-sectional view taken along line 2—2 of FIG. 1 showing the invention from the side.

FIG. 3 is a longitudinal-sectional view taken along line 3—3 of FIG. 2 showing the invention from the top.

FIG. 4 is a longitudinal-sectional view like FIG. 3, but showing the engine configuration in another operative position.

FIG. 5 is a cross-sectional view of a cylinder and piston taken along line 5—5 of FIG. 4.

FIG. 6 is a perspective view of the piston, saddle and yoke components of the invention showing the piston in partial sectionalized form for illustrative purposes.

FIG. 7 is a sectional view of a cylinder with the piston at its top and the cam follower at zero degrees or top dead center.

FIG. 8 is a sectional view showing the cam follower at 30°.

FIG. 9 is a sectional view showing the cam follower at 150°, illustrating that the cam follower travels 120° between the opposing involuted cams or dwell cups during the power stroke of the piston.

FIG. 10 is a sectional view of the fuel being drawn into the cylinder as the piston begins its upward movement while compressing the fuel mixture already above the cylinder.

FIG. 11 is a sectional view of the piston at the top of the cylinder and the fuel mixture compressed prior to detonation.

FIG. 12 is a sectional view of the fuel mixture detonated forcing the piston downward, opening the exhaust port to allow the exhaust gases to escape while also forcing the fuel mixture below the piston into the transfer ports.

FIG. 13 is a sectional view of the piston at the bottom of the cylinder and the transfer port opened to release the fuel mixture into the upper cylinder chamber, and expel any remaining exhaust gases out the exhaust port.

FIG. 14 is an exploded perspective view of the cylinder head and neck, illustrating the exhaust ports, the transfer ports, the inlet port, the spark plug hole in the cylinder bore of the cylinder head and the through hole for the connecting rod in the cylinder neck.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment herein described is not intended to be exhaustive or to limit the invention to the precise form disclosed. It is chosen and described to explain the principles of the invention and its application and practical use to enable others skilled in the art to utilize the invention.

The preferred embodiment of the invention is a four-cylinder, two-stroke engine. The concepts that exist in this invention are applicable to other types of engines such as multiple-cylinder, four-stroke engines.

Referring now to the drawings, FIG. 1 illustrates the preferred embodiment of the twin-opposing four--cylinder, two-stroke internal combustion engine **1**. For descriptive purposes, engine I can be referred to as having similar halves sharing a flywheel **20**. Thus, only one such engine half will be described in detail with similar reference numerals being used for like functioning components of both halves.

Each engine half la, lb includes a pair of oppositely located pistons **10**, a cylinder **26** for each piston **10**, and a portion of a crankcase **50** supporting a journalled flywheel **20** therein. Each crankcase half **50*a*, 50*b*** includes an outer part **52** and an inner part **54** forming in conjunction with the other crankcase half a central chamber **102** for the internal components of engine **1**. Outer part **52** and inner part **54** are fastened to other crankcase half by screws **94**. Crankcase **50** supports a journalled flywheel **20** in central chamber **102** by a bearing **104**. Bearing **104** is seated in the cavity defined by inner parts **54** so as to support flywheel **20** and allow it to rotate about an axis perpendicular to the piston movement. Crankcase **50** has a side opening **21** for a sectored portion of flywheel **20** to mesh with a suitable power input gear (not shown). Additionally, outer part **52** and inner part **54** form in conjunction the openings **53** for interfitting cylinder neck parts **28**, as shown in FIG. 2.

As shown in FIG. **14**, each cylinder **26** includes a head part **27** and a neck part **28**. Each head part **27** includes top opening **31** for an interfitting spark plug **24**, a lower annular lip **25** for interfitting with neck part **28** and which defines an opening **33** which is part of the cylinder bore **4**, two exhaust ports **46** for allowing the discharge of the exhaust gases out of cylinder bore **4**, diametrically located transfer ports **16** for allowing the passage of the fuel mixture from below the piston to above the piston and cooling flanges **30** for dissipating the heat generated within the head part, all as shown in FIG. **14**. Each neck part **28** has an annular recess **29** for accepting head part lip **25**, an inlet port **14** for allowing the passage of the fuel mixture into the cylinder bore **4** below the piston, and necked collar part **100** for fitting into crankcase opening **53**.

Each cylinder **26** contains a piston **10** located in bore **4**. Each piston **10** includes a skirt **76** with opposing slots **74** and circumferential grooves **40**, as shown in FIG. 6. Slots **74** are for reducing the effects of heat warping upon each piston **10** and to allow skirt **76** to flare outwardly into contact with cylinder bore **4** so as to achieve a greater vacuum below the piston during engine operation. Rings **41** are carried in grooves **40**. The length of each piston **10** is preferably longer than the length of transfer ports **16**.

The pair of pistons **10** are coaxially interconnected by a yoke **42**. Each piston **10** includes opposing lugs **75** which extend from the piston top wall **11** spacedly along the interior of skirt wall **76**, as shown in FIG. 6. Lugs **75** have aligned holes **78**. As shown in FIG. **5**, a hollow retainer pin **79** extends into each hole **78**. Retainer pin **79** is held within piston **10** by a pair of washers **81** each placed over one end of the pin and is secured by a retainer screw **83** which extends through the hollow pin. A saddle **62** is pivotally carried between lugs **75** by retainer pin **79** inserted with clearance through the saddle piston hole **66**. Saddle **62** has aligned wrist pin holes **70**. Wrist pin **82** extends into each hole **70** and is held by a screw connection. A rod **12** is pivotally carried between the saddle walls **68** by wrist pins **82** inserted with clearance through the rod wrist pin hole **72**. The end of rod **12** abuts against the saddle seat **64** for ensuring no longitudinal loading is experienced by wrist pin **82** or skirt **76** during the power stroke of pistons **10**. Clearance exists between rod **12** and saddle walls **68** for allowing lateral movement of piston **10** relative to rod **12** so as to achieve uniform piston wear. The oppositely aligned ends of rods **12** coaxially join a U-shaped cam member **43** to form yoke **42**. Cam member **43** is located in internal chamber **102**. Each rod **12** extends from internal chamber **102** through the lower end wall **140**, in which a hole **106** is provided in each neck part **28**, and into cylinder bore **4**.

Each cam member **43** includes two side walls **110** and a back wall **112**. Each side wall **110** defines an involuted cam or dwell cup **44**, as shown in FIG. **6**, herein described later. The center of each dwell cup **44** is referred to as either top dead center **44*a*** or bottom dead center **44*b***. This nomenclature is relative to the position of each individual piston **10**. For some applications of engine **1**, dwell cups **44** can have varying curvatures as required to gain the desired engine efficiency during fuel detonation. This may be achieved by using an insert a shoe (not shown) in cam member **43** that has the desired shape of dwell cups **44**. In this preferred embodiment dwell cups **44** have symmetrical curvatures. Back wall **112** of cam member **43** can be adapted for imparting auxiliary motion to a second machine through a suitable capped opening **130** in crank case **50**.

Each yoke **42** is connected to flywheel **20** through a cam follower **32**, as shown in FIG. **2**. Cam followers **32** form a part of flywheel **20** and are diametrically located on opposite sides of the flywheel within chamber **102**. The contact surface of each cam follower **32** is in the form of a bearing **35**. Each cam follower **32** fits with rolling clearance between side walls **110** of cam member **43**.

Lubricating oil is placed in chamber **102** for reducing friction wear of the engine components during operation. An oil passage **47** is provided in each inner part **54**, connected to neck part **27** and head part **27**. Passage begins at an inlet port **49** within internal chamber **102** and terminating in an outlet port **45** located in each cylinder bore **4**, as shown in FIG. **4**. Each outlet port **45** is located so piston rings **41** are lubricated as piston **10** reaches the bottom of its stroke, as shown in FIG. **3**. During the operation of engine **1**, the movement of the internal components located in crankcase **50** act as a pump forcing the oil in chamber **102** into inlet port **49**, along passage **47**, out each port **45** and onto rings **41**. Negative pressure created from piston **10** movement aids in drawing the oil onto rings **41**. The flaring of piston skirt **76** serves to obstruct the release of oil into bore **4** when rings **41** are not in contact with inlet port **45**.

Each yoke rod **12** is necked at the cam member junction **114** for preventing oil in chamber **102** from being injected into cylinder bore **4** through opening **106** during engine **1** operation. A seal **107** is located at opening **106** of each neck **28** and extends about rod **12** to also assists in obstructing oil from being pumped into cylinder bore **4**. Cylinder bore **4** is also sealed at its innermost end by its neck part **28**.

In the operation of engine **1**, pistons **10** act in concert to rotate flywheel **20** by means of yokes **42**. Each yoke **42** serves to translate the longitudinal coaxial motion of each pair of opposed pistons **10** into rotational movement of flywheel **20**. This occurs when a piston **10** moves down cylinder bore **4** thereby pushing yoke **42** along its longitudinal axis. As each yoke **42** is moved it carries with it the connected cam follower **32**, thus causing flywheel **20** to rotate. Flywheel **20** will rotate 360° about its axis as each yoke **42** is pushed down and back.

Piston **10** movement occurs upon the detonation of a fuel mixture **120** in cylinder **26**. Fuel mixture **120** cycles through each cylinder bore **4** in the following manner. The first outward stroke of each piston **10** causes a negative pressure below the piston to draw fuel mixture **120** from inlet port **14** into cylinder bore **4**, as shown in FIG. **10**. The following inward stroke of piston **10** forces fuel mixture **120** from below the piston into transfer ports **16**, as shown in FIG. **12**. When piston **10** reaches the bottom of cylinder bore **4**, transfer ports **16** open above the piston and allows the pressurized fuel mixture **120** to flow into the area above the piston, as shown in FIG. **13**. The succeeding outward stroke of piston **10** further compresses fuel mixture **120** above the piston, as shown in FIG. **11**. When piston **10** reaches the top of cylinder bore **4**, fuel mixture **120** is detonated by a spark from sparkplug **24**. The subsequent explosion causes piston **10** to move inwardly; this motion is commonly referred to as the power stroke. As piston **10** reaches the bottom of cylinder bore **4** during its power stroke, exhaust ports **46** open to allow the burnt or exhaust gases **122** to expand and flow out of cylinder bore **4** through exhaust ports **46**, clearing it to receive nearly simultaneously a fresh charge of fuel mixture **120**, as shown in FIG. **13**. The cycle is then repeated.

The presence of dwell cups **44** in yokes **42** increases the engine's horsepower by regulating the movement of pistons **10**. The outward movement of each piston **10** is substantially stopped when its associated cam follower **32** travels along the concave surface of dwell cup **44** during the power stroke of its oppositely located, paired piston. By stopping piston movement at the top its compression/detonation stroke, fuel mixture **120** is compressed into a fixed volume and can experience a substantively complete burn before the piston moves and enters its power or inward stroke. Further, hydrocarbons or nitrous oxides are reduced and sometimes even eliminated from exhaust gases **122**, because the fuel mixture **120** is more thoroughly consumed. Thus, contamination of subsequent fresh charges fuel mixture **120** entering into cylinder bore **4** by unburned hydrocarbons will be reduced and perhaps even eliminated.

This process begins when each cam follower **32** reaches the cam or concave surface of its associated top dwell cup **44***a* at −30° There, fuel mixture **120** is ignited. For 60° of rotation, cam follower **32** travels along the dwell cup surface which is curved to match the radial sectored movement of the cam follower, stopping the movement of piston **10** while fuel mixture **120** is consumed. At +30°, piston **10** begins its power stroke, as shown in FIG. **8**. The expansive forces created from the detonation of fuel mixture **120** moves piston **10** inward, pushing yoke **42** against cam follower **32** which turns flywheel **20**. When cam follower **32** reaches 150°, it begins to travel along the bottom dwell cup **44***b*, as shown in FIG. **9**. Piston **10** will again be substantially stopped in movement for 60° until cam follower **32** reaches 210°. This allows the detonation process to occur in the opposite cylinder **26**. Piston **10** then begins its succeeding outward stroke once cam follower **32** reaches 210° and is forced out along cylinder bore **4** into its compression/detonation stroke by the connected opposite paired piston **10** which is being forced inward during its own power stroke.

Each pair of pistons **10** has two power strokes (one for each piston) per revolution of flywheel **20**. Each piston pair operate in synchronous translation and 180° out of phase with the other pair of pistons. Thus, fuel mixture detonation occurs at each piston **10** in its outermost position simultaneously. Hence, the outermost piston **10** of one piston pair will be in its power stroke as the offset oppositely located outward piston **10** of the other piston pair is also in its power stroke, and in concert, the two pistons will function to rotate flywheel **20**.

The presence of cylinder end wall **140** also serves to maximize engine's **1** creatable horsepower by increasing the density of fuel mixture 120. Because cylinder bore is enclosed at its lower end and thus separated from internal chamber **102**, fuel mixture **120** achieves a greater density when being compressed into transfer ports **16** than conventional engines. Thus, when fuel mixture **120** is consumed, the increase in density equates to an increase in generated power. The thickness of cylinder end wall **140** thickness can be varied by installing specially machined neck parts **28** so as to alter the fuel mixture density as desired.

The location and size of exhaust ports **46** serves to maximize the amount of horsepower piston **10** can generate during its power stroke. Exhaust ports **46** are positioned to open when the opposite paired piston **10** begins detonation. Thus, a longer power stroke is achieved resulting in increased horsepower than can be gained using conventional cylinders.

During operation of engine **1**, noise generated by yoke **42** impacting against cam follower **32** is reduced because of the presence of dwell cups **44**. Also during the operation of engine **1**, yoke **42** may have a tendency to rotate about the longitudinal axis during translation. An I-beam **5** is fastened to each crankcase cover **6** so as to prevent such rotation.

It is understood that the above description does not limit the invention to the details given, but may be modified within the scope of the following claims.

I claim:

1. An engine comprising a housing which includes a central crank case having a chamber therein and two oppositely located cylinders, one of said cylinder on each side of said crank case with said crank case chamber therebetween, a piston shiftably supported in each cylinder, a yoke connected between said pistons and extending through said crank case chamber, said yoke being shiftable between first and second reciprocal positions within said crank case chamber upon alternating movement of said pistons within said cylinders, a flywheel journalled in said crank case chamber, means carried by said flywheel accessible from a crank case opening for imparting driving power to a power input mechanism during flywheel rotation, said yoke including a cam member located generally centrally between said pistons, said flywheel including means engaging said yoke cam member for imparting rotation to the flywheel upon movement of said yoke between its said first and second positions, said yoke cam member having camming means contacting said flywheel means for imparting controlled movement to each piston during fuel detonation within its said cylinder, and means for detonating said fuel within each cylinder.

2. The engine of claim **1** wherein said yoke cam member includes opposing side walls, said flywheel means being a protruding follower positioned between said side walls, each side wall having a generally undulate shape, said follower contacting one said of side walls when said yoke is in said first position and contacting the other of said side walls when said yoke is in said second position.

3. The engine of claim **2** wherein each side wall includes a centered arcuate concave sector having a radius of curvature approximating the radius of movement of said follower upon rotation of said flywheel.

4. The engine of claim I wherein said yoke cam member includes a wall part connecting said side walls.

5. The engine of claim I wherein said yoke includes coaxial rods extending in opposite directions from said yoke cam member, each piston connected by a saddle to one end of said rod, each rod secured by a wrist pin to a said saddle in abutting contact with said saddle.

6. The engine of claim 5 wherein each piston includes an end wall and an extending skirt, a pair of spaced lugs extending from said piston end wall, said saddle positioned between and pivotally secured to said lugs, said lugs being separated from said skirt.

7. The engine of claim 6 wherein each skirt flares outwardly from said piston end wall.

8. The engine of claim 7 wherein each said skirt includes an end edge and a slit extending from said end edge towards said piston end wall, each cylinder having a bore with side, a said piston located in each cylinder bore with its said skirt at said slit end edge contacting said cylinder bore side.

9. The engine of claim 1 wherein each cylinder includes a bore defined by opposing end walls and a connecting side wall, said piston located within each cylinder bore, said yoke including a rod extending in a sealed relationship through one of said bore end walls.

10. The engine of claim 9 wherein said housing has a passage extending within said crank case and each cylinder from said crank case chamber into each cylinder bore, said passage constituting means for directing oil from a reservoir in said crank case chamber to each piston.

11. The engine of claim 10 and including pump means within said crank case chamber for forcing said oil into said passage.

12. The engine of claim 11 wherein said pump means includes said yoke and said flywheel.

13. The engine of claim 9 wherein each of said cylinder bores includes a fuel inlet port located adjacent said one bore end wall between said piston end wall and said one cylinder bore end wall, means for conducting said fuel from said cylinder bore between said piston and said one cylindrical bore end wall to between the piston and the other said bore end wall, and an exhaust port located in said bore side wall between said piston and said other bore end wall when the piston is nearest said one bore end wall.

14. The engine of claim 9 wherein each said cylinder includes separable neck and head parts, each neck part including said one bore end wall and being detachably connected between said head part and said crank case.

15. An engine comprising a housing which includes a central crank case having a chamber therein and two pairs of oppositely located parallel cylinders, one of said cylinders of each pair located on each side of said crank case with said crank case chamber therebetween, a piston shiftably supported in each cylinder forming aligned pistons for each pair of cylinders, a yoke connected between said aligned pistons and extending through said crank case chamber, each yoke being shiftable between first and second reciprocal positions with said crank case chamber upon alternating movement of said aligned pistons within their respective cylinders, a flywheel journalled within said crank case chamber, means carried by said flywheel accessible from a crank case opening for imparting driving power through a power input mechanism during flywheel rotation, each said yoke including a cam member located generally centrally between said aligned pistons, said flywheel including means engaging said yoke cam member of each yoke for imparting rotation to the flywheel upon movement of each yoke between its said first and second positions, each yoke cam member of a said yoke including camming means contacting said flywheel means for imparting controlled movement to each said piston connected to said yoke prior to the commencement of the power stroke of the piston.

16. The engine of claim 14 wherein each yoke cam member includes opposing spaced side walls, said flywheel means having diametrically positioned and oppositely protruding followers, each follower positioned between said side walls of said yoke cam member.

17. The engine of claim 15 wherein each side wall of each said yoke cam member has a generally undulant shape, said follower being positioned between said side walls of said yoke cam member and contacting one of such said side walls when said yoke is in said first position and contacting another said side wall when said yoke is in said second position.

18. The engine of claim 16 wherein each said yoke cam member side wall includes a centered arcuate concave sector having a radius of curvature approximating the radius of movement of its contacting follower upon rotation of said flywheel.

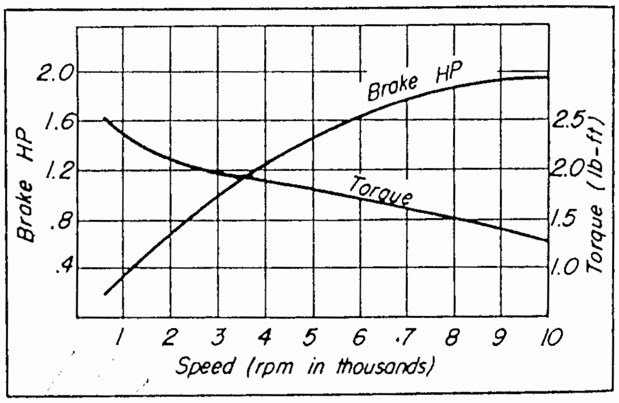
* * * * *

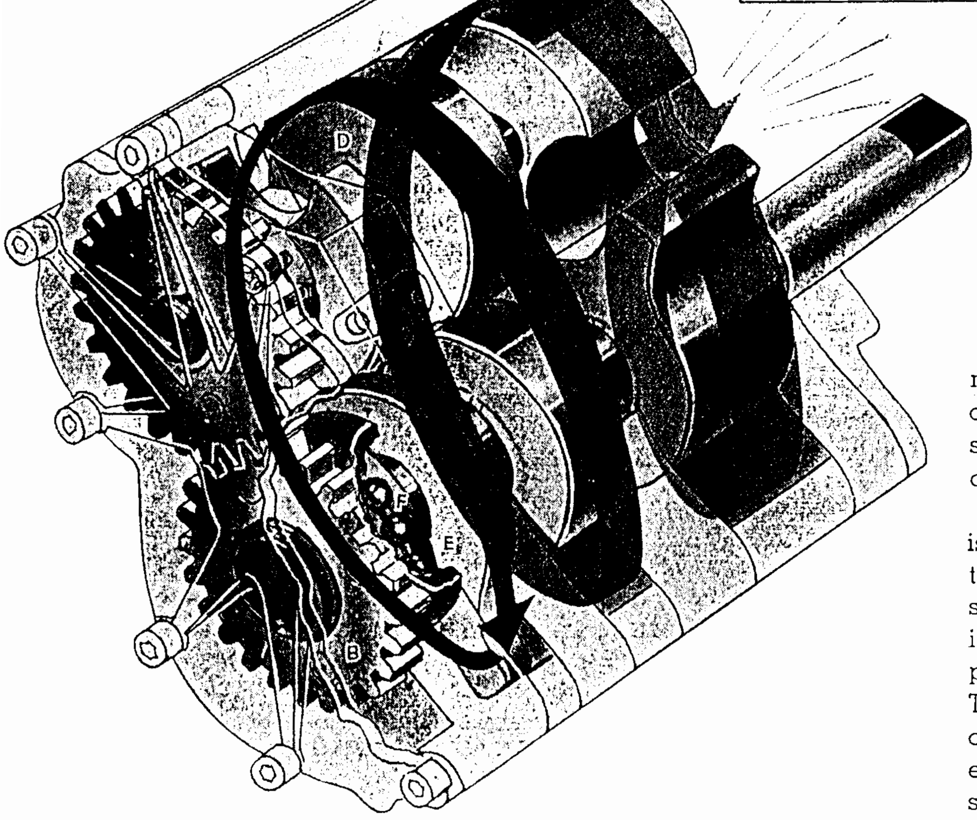
Machine Design
July 1948, p. 98

Scanning THE FIELD for Ideas

Pneumatic motor illustrated in sectional view below utilizes positive displacement rotary pistons. Designed by Berry Motors Inc. to employ the multiple-expansion principle, it has three thermodynamically balanced stages. Compressed air enters the first stage at receiver tank pressure, drives the piston in this cylinder through its power stroke, passes to the next cylinder, continues to expand, and successively drives the second and third pistons through their power strokes. Upon completion of the third power stroke, the air is exhausted at near atmospheric pressure.

Staging and compounding are accomplished without the use of valving, the pistons offering the only resistance to the continuous flow of air. By this method of compounding, force is obtained from both the expansion and the velocity of the air, resulting in an increase in torque at all speeds. To further increase torque at low speeds an adjustable bypass valve is provided between the inlet and second stages. This valve is arranged so as to permit the flow of high pressure air from the inlet to the second stage as load conditions require.





In the sectional drawing (A) is a band showing flow of air through the three compounded stages, (B) timing gears, (C) inlet, (D) abutment valve, (E) pistons, and (F) bearings. Torque and horsepower characteristics of this ¾-horsepower motor are plotted against speed in the curves above.

TURBINE AIR MOTOR

PRODUCT SPECIFICATION

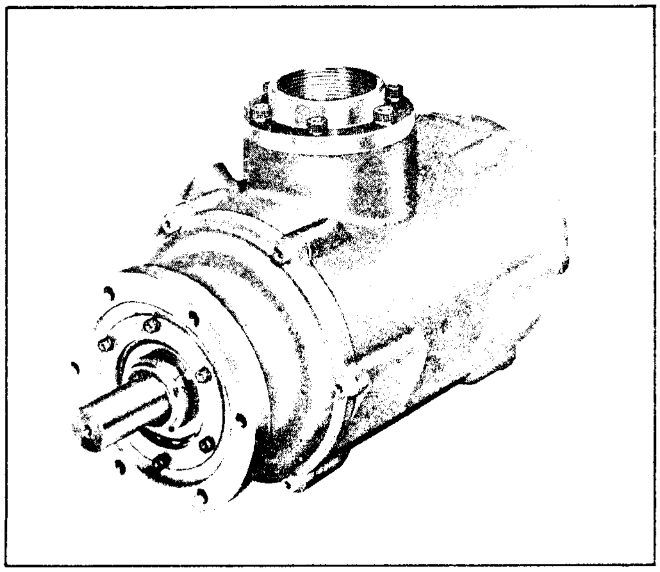
GENERAL INFORMATION

The Series 51A turbine powered air motor is a 5 to 95 horsepower capacity drive system designed to be used in a wide range of industrial applications. This motor consists of a single stage inpulse turbine coupled to an integral planetary gear reduction set. The turbine and gear reduction components are contained within a very compact package approximately 6 inches in diameter and 12 inches long, which weighs 30 pounds. The Series 51A turbine section incorporates a precision mechanical seal, making it suitable for use with natural gas as well as compressed air. Also, the selection of materials for the internal parts of the motor will allow the turbine to be driven with sour natural gas. Since a turbine air motor fully expands the pressurized drive gas, it is the most efficient type of pneumatic motor available in this horsepower class. Like other turbine air motors, the Series 51A requires no lubricant in the drive gas, therefore eliminating problems with wear as commonly found in vane type air motors. To size the horsepower level of the motor, the Series 51A has a nozzle plate which contains from one to twenty-one nozzle passages which meter air to the turbine wheel. The table below shows the motor's performance for four different numbers of nozzles: 3, 9, 15 and 21. The Series 51A is extremely flexible because of the many possible variations in its mechanical configuration and operational usage. For proper selection for your application, contact your local TDI representative or Tech Development.

SERIES 51A AIR MOTOR PERFORMANCE
For 90 psig (620 kPa) air pressure
at 70°F (21°C) temperature

Air** Motor Model	Starting Torque lb-ft (N•m)	Power Output* hp (kW)	Torque Output* lb-ft (N•m)	Air Consumption scfm (m³/min)
51A-21	233 *(316)*	92 *(68)*	172 *(233)*	1565 *(44.3)*
51A-15	167 *(226)*	66 *(49)*	124 *(168)*	1118 *(31.6)*
51A-09	100 *(135)*	39 *(29)*	74 *(100)*	671 *(19.0)*
51A-03	33 *(44.8)*	13 *(9.7)*	25 *(34)*	224 *(6.3)*

*At output speed of 2770 rpm
**Version with 9.0:1 ratio speed reducer



APPLICATION ADVANTAGES

- Turbine motors are smaller and lighter than vane and piston motors of equivalent output.
- Turbine motors offer 25% more power output than vane motors for the same air consumption.
- No lubricant needed in the drive air, therefore no failures due to improperly lubricated supply air.
- Turbine motors can be run under full load for extended periods with no harm - they cannot be burned out.
- Turbines are tolerant to dirt in the drive air.
- Turbines have good low and high temperature performance.
- Turbine motors may be easily modified to raise or lower the horsepower/air consumption range.
- Turbines have a higher stall or starting torque than an equally rated vane motor - there is no droop in torque at zero speed.

TECH DEVELOPMENT INC.

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Telephone (513) 898-9600 / TWX 810-472-2822

SERIES 51A TURBINE AIR MOTOR

OPERATION & PERFORMANCE

The curves on the rear side of this brochure show the horsepower and torque capacities of four different nozzle variations of the Series 51A over its operating RPM range at a drive pressure of 90 psig. The unit can be operated on compressed gas at pressures from 50 psig to 150 psig. Lower pressures will result in lower output, but lower gas consumption, and vice versa for higher pressure. The power output with natural gas would be 10% higher than the graph data, which is based on compressed atmospheric air. The internal gear reducer is available with self-contained grease lubrication or continuously oiled lubrication as required by the application. The gearing is capable of carrying the maximum output of the 51A-21 version on an intermittent duty cycle, but for continuous operation, the 33 hp capability of the 51A-09 version at 90 psig should not be exceeded to insure long life. Gear reduction ratios of 7.5:1, 9.0:1 and 11.4:1 are available, which change the torque relationship to horsepower and rpm. Clockwise or counterclockwise shaft rotation is also available and should be specified when ordering.

For applications requiring speed control due to fluctuating loads on the motor, the Series 51A air motor can be furnished with an optional speed control system. This consists of a magnetic speed sensor, a control box, a motorized air flow control valve in the supply line to the motor and, a rapid shut-off valve. In installations where external electric power is not available to operate the control, a small alternator can be furnished within the motor. This serves the dual purpose of providing speed sensing and the electric power necessary to operate the control.

SPEED CONTROL

- An electronic control circuit, operating an electric servo motor driven valve
- RPM regulation to ± 3% within operating limits
- The system is self-energized, requiring no external source of electrical power (optional feature)
- Output speed control can be maintained from 0 to 100% of rated load
- Speed may be adjusted from 1750 rpm to 3000 rpm
- The turbine and the control valves will operate with compressed air or natural gas
- System can be easily modified for specific applications

OVERSPEED CONTROL

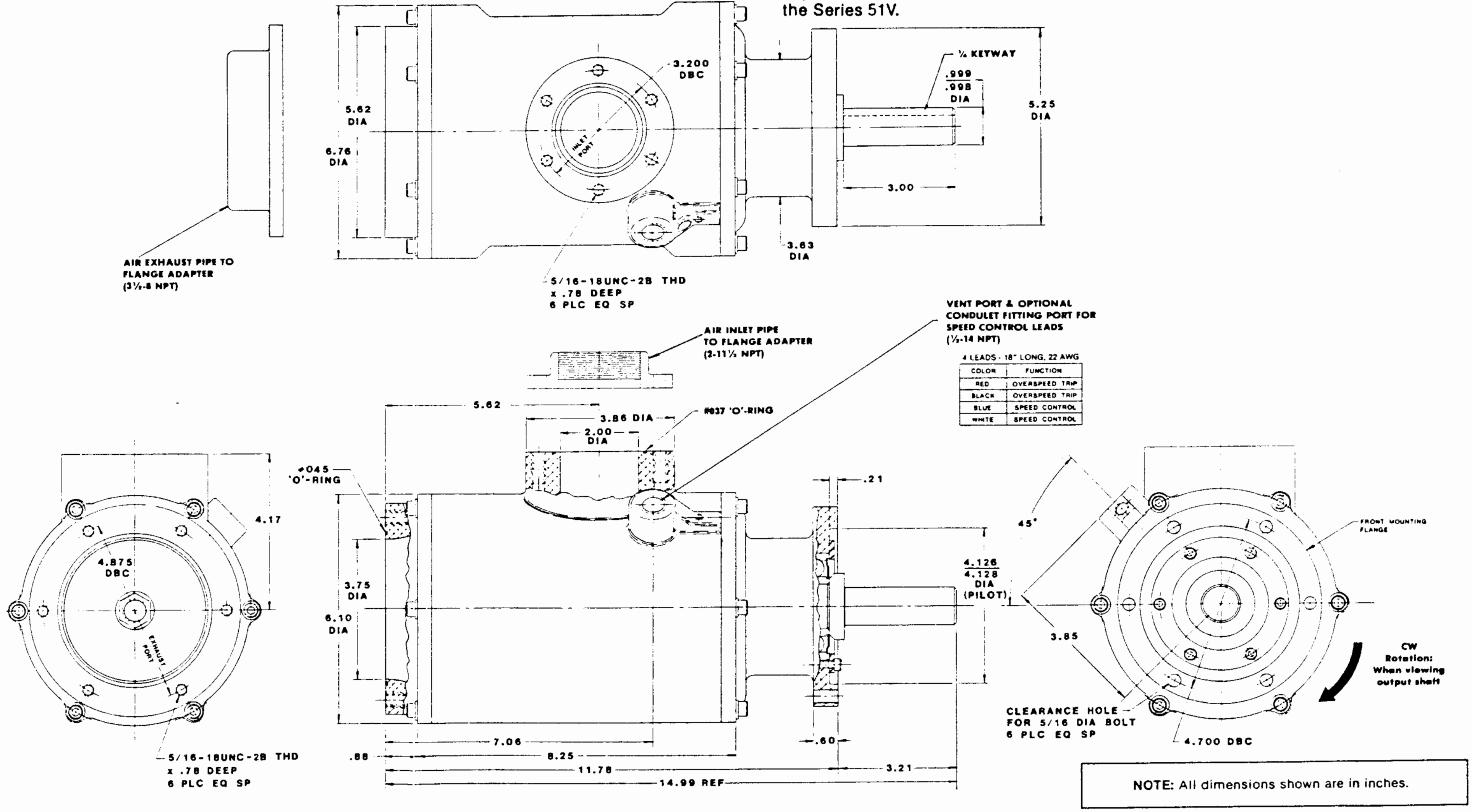
- Is a solenoid valve with manual reset
- Will activate when an overspeed of 3555 rpm ± 10% is sensed for the Series 51A
- Will activate if either coil of the two-coil alternator in the air motor fails (when self-energized)
- Emergency shut-down circuit can be tested from control box to insure functioning

OTHER CONTROL BOX FUNCTIONS

- A digital or analog speed readout meter
- Increased RPM regulation precision
- Variable speed output via external sensors

INSTALLATION FEATURES

The drawing on this page shows the installation features and dimensions of the Series 51A turbine air motor. The motor has a face mounting provision which provides for 6 - 5/16" bolts on a 4.7" diameter bolt circle. Drive gas to the motor is fed into the top mounted boss which has a 2" diameter inlet, and is exhausted aft of the motor through the 3.50" diameter rear port. Adapter fittings are available for the inlet and exhaust ports to convert from a bolt flange to a pipe thread. Although not illustrated in this brochure, a foot mount version of the Series 51A is available. This configuration is required when continuous lubrication of the gearbox is necessary as previously explained. The foot mounted version for horizontal applications is the Series 51H; for vertical installations, the Series 51V.


AIR EXHAUST PIPE TO FLANGE ADAPTER (3½-8 NPT)
5.62 DIA
6.76 DIA
3.200 DBC
INLET PORT
5/16-18UNC-2B THD x .78 DEEP 6 PLC EQ SP
3.63 DIA
¼ KEYWAY
.999 .998 DIA
5.25 DIA
3.00
AIR INLET PIPE TO FLANGE ADAPTER (2-11½ NPT)
VENT PORT & OPTIONAL CONDULET FITTING PORT FOR SPEED CONTROL LEADS (½-14 NPT)
5.62
3.86 DIA
2.00 DIA
#037 'O'-RING
#045 'O'-RING
4.17
4.875 DBC
EXHAUST PORT
5/16-18UNC-2B THD x .78 DEEP 6 PLC EQ SP
3.75 DIA
6.10 DIA
.21
4.126 4.128 DIA (PILOT)
.60
.88
7.06
8.25
11.78
3.21
14.99 REF
45°
3.85
FRONT MOUNTING FLANGE
CW Rotation: When viewing output shaft
CLEARANCE HOLE FOR 5/16 DIA BOLT 6 PLC EQ SP
4.700 DBC

4 LEADS - 18" LONG, 22 AWG

COLOR	FUNCTION
RED	OVERSPEED TRIP
BLACK	OVERSPEED TRIP
BLUE	SPEED CONTROL
WHITE	SPEED CONTROL

NOTE: All dimensions shown are in inches.

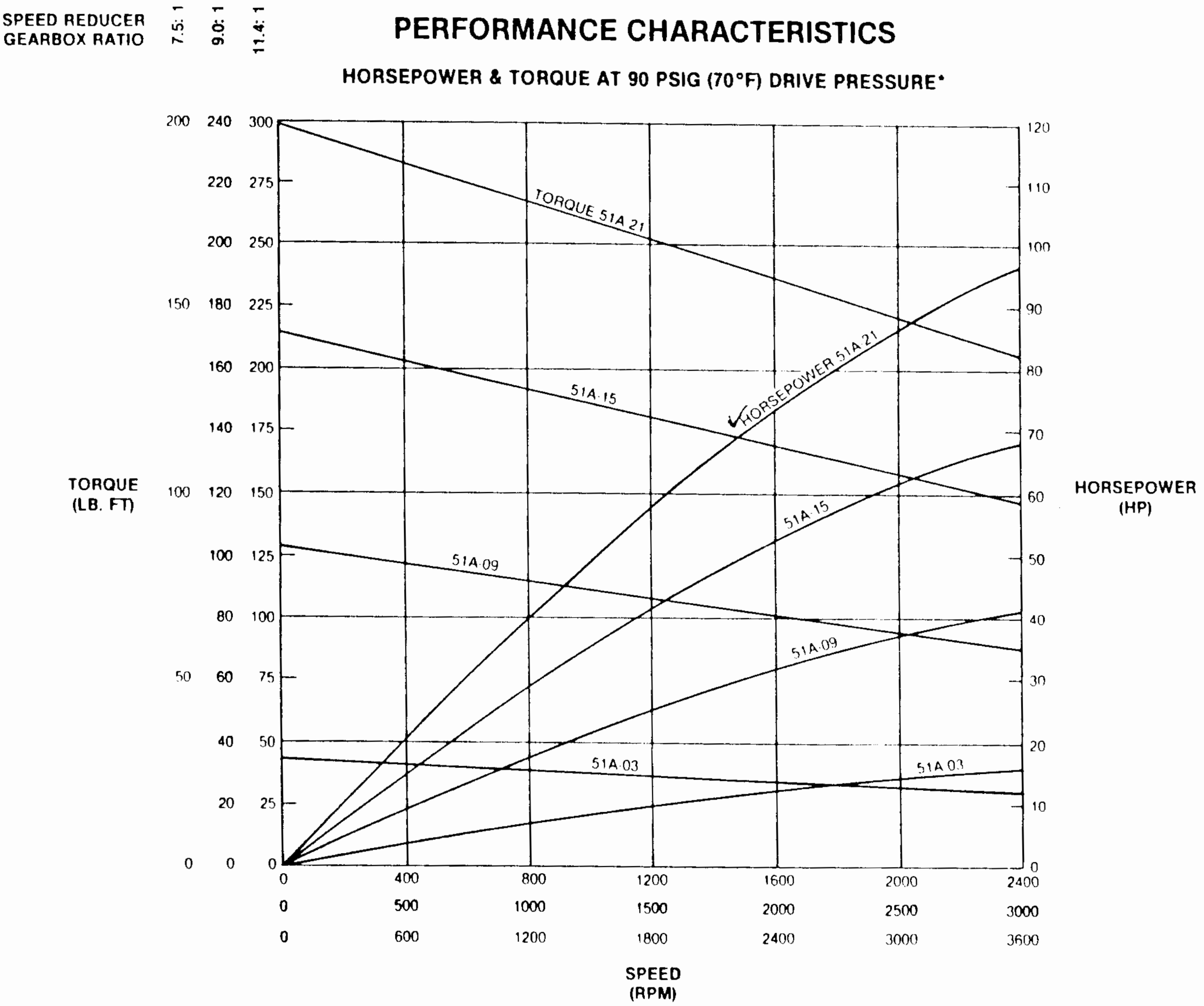
TECH DEVELOPMENT INC.

6800 Poe Ave., P.O. Box 1400-0 Dayton, Ohio 45414
Telephone (513) 898-9600 / TWX 810-472-2822

Series 51A Turbine Air Motor

PERFORMANCE CHARACTERISTICS

HORSEPOWER & TORQUE AT 90 PSIG (70°F) DRIVE PRESSURE*



AIR CONSUMPTION RATES** For 90 psig (620 kPa) air pressure at 70°F (21°C) temperature	
Model	**scfm**
/ – 51A-21	1565
51A-15	1118
51A-09	671
51A-03	224

ENGLISH TO METRIC CONVERSIONS

POWER (Horsepower to Kilowatts)
Horsepower (hp) × 0.7457 = Kilowatts (kW)
TORQUE (Pound-Feet to Newton•Meters)
Torque (lb.-ft.) × 1.3558 = Torque (N•m)
AIR FLOW (Cubic Feet/Minute to Cubic Meters/minute)
Flow (sfcm) × 0.0283 = Flow (M^3/min.)
AIR PRESSURE* (Pounds/Sq. Inch to Kilo Pascals)
Gauge Pressure (psig) × 6.8889 = Pressure (kPa)

*Note: 14.5 psi = 1 bar = 100 kPa = $1 \times 10^5 \frac{\text{Newtons}}{\text{meter}^2}$

***NOTE:** The curve above illustrates the performance of the Series 51A for a 90 PSIG drive pressure. This motor may be operated effectively over a range of pressures from 50 PSIG to 150 PSIG. The horsepower, torque and air consumption will vary due to these different pressures, and this performance data can be provided by Tech Development on request.

****NOTE:** A characteristic of turbine motors is that the air consumption remains constant for each dash (-) version over the entire RPM range for a constant pressure drive gas. For the **Series 51A**, there are a total of twenty one dash (-) versions which can be produced for O.E.M. applications which require optimized performance.

Tech Development Inc., Feb. 1981, AN81-002

COMPARISON OF TURBINE AND VANE AIR MOTORS VS. ELECTRIC MOTORS

CHARACTERISTIC	TURBINE AIR MOTORS	VANE AIR MOTORS	ELECTRIC MOTORS
Horsepower Capabilities	Normally available in ranges from fractional horsepower through 1000 HP. Majority are 100 HP or less in capability.	Designs available up to 100 HP, however, majority are manufactured in the fractional through 10 HP output category.	Available in fractional horsepower through 20,000 HP outputs. In the U.S., 67% of all AC motors are in the 1 to 20 HP output category.
Operating Speed	Designs available to 100,000 RPM. Typical commercial designs operate efficiently under load in the 10,000 RPM to 50,000 RPM range. Efficient running at lower output speeds requires gear reduction. Speed control is simply accomplished by the use of a valve in the drive air line.	Under load, vane motors operate efficiently in the 2000 to 10,000 RPM range. Efficient running at lower output speeds requires gear reduction. Speed control is accomplished by a valve in the drive air line.	Normal AC induction and synchronous motors operate at 3600 and 1800 RPM outputs. High frequency snychronous motors are available up to 24,000 RPM. Lower RPM's require gear reduction. Variable speed is an expensive feature, particularly at higher RPM's.
Torque	Maximum torque is achieved at zero RPM and falls off nearly linearly to zero torque at free speed. Stall Torque is approximately twice the torque at rated power.	Torque reaches its highest value slightly beyond zero RPM when starting and declines linearly to zero torque at free speed. Stall Torque is approximately twice the torque at rated power.	Starting torque can vary from 40% to 300% of torque at rated power, depending on type of motor selected.
Speed-To-Load Response	Increasing the load will decrease the speed of an air motor, until its torque matches the load imposed on it. An air motor can be stalled without harm. It will increase its speed when the load is reduced or the airflow to it increased. Overspeeding may fail the bearings, but not the turbine, if properly designed.	Increasing the load will decrease the speed of an air motor, until its torque matches the load imposed on it. An air motor can be stalled without harm. It will increase its speed when the load is lessened or the airflow to it increased. Overspeeding will burn up the vanes and may fail the bearings and score the walls.	Electric motors will maintain rated speed regardless of load. This constant speed is desirable in many applications. An AC motor must be run at close to its rated load, otherwise the motor will overheat.
Operating Efficiencies	A turbine motor can utilize 70% of the energy available in the compressed air. The air consumption per horsepower output is lower than an equivalent vane motor. There is a cost associated in using an electric motor to compress the air. Icing of the exit ports is not a problem.	A vane motor can only utilize 30% of the stored energy in the compressed air. Air consumption is higher per horsepower output than with a turbine. Still a penalty in electric cost to compress the air. The exit ports may ice up.	If the electric motor can be used at the point where the rotary mechanical power is needed, it is the more cost effective type of drive. Other characteristics may, or may not, preclude its application.
Environmental Factors	• Explosion Proof by its very nature. • Cannot be burned out by stalling or overloading. • Self-cooling due to expansion of compressed air. • Requires the use of mufflers in exhaust air line to reduce noise level. • Resistant to contaminated drive air.	• Explosion proof by its very nature. • Cannot be burned out by stalling or overloading. • Self-cooling due to expansion of compressed air. • Requires the use of mufflers in exhaust air line to reduce noise level. • Needs very clean drive air.	• If motor is placed in explosion proof housing, this adds to cost, weight and danger of overheating. • Off-design speed operation due to load or current variations can cause motor to overheat. • Heat generation in windings require insulation and/or cooling air flow at all times. • Motors are quiet in operation.

CHARACTERISTIC	TURBINE AIR MOTORS	VANE AIR MOTORS	ELECTRIC MOTORS
Servicing & Maintenance	Turbine motors have no rubbing parts to wear out. Bearings are normally grease packed and shielded. These must be examined on a periodic basis. No lubricant is required in the drive air. Units may be serviced in the field. Greater corrosion resistant materials can be used to enhance reliability.	Vanes will wear even at moderate speeds due to rubbing on cylinder walls. Lubricant is required in the drive air. Motors must be overhauled when vane wear becomes excessive, or bearings wear out. Units may be serviced in the field.	Electric motors require little maintenance. Brushes must be replaced on some units when worn. Lubrication of bearings may be required periodically. When maintenance is required, usually involves factory or authorized overhaul center and skilled technicians. Power supplies are also complex devices that can fail.
Volume & Weight Considerations	Turbine driven air motors have a much more favorable ratio of horsepower-per-unit-volume and horsepower-per-unit-weight than either vane air motors or electric motors.	Vane driven air motors, while not as compact as turbine air motors in the integral HP sizes, do offer greater output per size and weight than comparably rated electric motors.	Normal commercial electric motors are several times heavier than air motors of equal horsepower output. Explosion-proofing adds additional weight and volume.
Installation Features	A turbine motor allows installation in any attitude. The lack of any need for lubricant in the drive air permits use in food processing industries, medical environments or electronic clean rooms. The turbine can be driven on air, nitrogen, freon or natural gas and can be adapted for steam.	A vane motor with proper lubrication can be run in any position. It can be run on a variety of gases, including natural gas, which allows its use in remote locations.	Higher horsepower electric motors are normally much heavier and larger than comparable output air motors. Mounting provisions become substantial considerations. Adequate ventilation must be provided due to cooling needs. Can only be used where there is a source of electrical power available.
Acquisition and Operational Costs	A turbine air motor by itself can be more expensive than a vane air motor. When gear reduction and lubrication systems are required of both motors, the unit costs are comparable. For power output at high rpm's (greater than 10,000 rpm) a turbine is the most cost effective approach. The cost and availability of compressed drive gas must be considered when designing an effective system. A turbine is more efficient and will use less drive gas than a vane motor.	Vane air motors are relatively inexpensive sources of compact rotary power in outputs under 5 HP. Gear reduction requirements and higher power outputs do add measureably to the cost. If the cost of additional compressed air capacity is added when needed, the system cost may equal or exceed turbine motors or electric motors. The cost of vane replacements and the need to provide in-line oilers add to the life cycle costs of vane motors.	Low horsepower electric motors are inexpensive due to high production runs. Larger horsepower units become increasingly expensive. The cost of supporting equipment such as power supplies, frequency convertors and overload protectors must be added to the acquisition cost when comparisons are made. Explosion-proofing and cooling protection can also add to the cost.

turbine air motors

...high performance rotary power
in a small package

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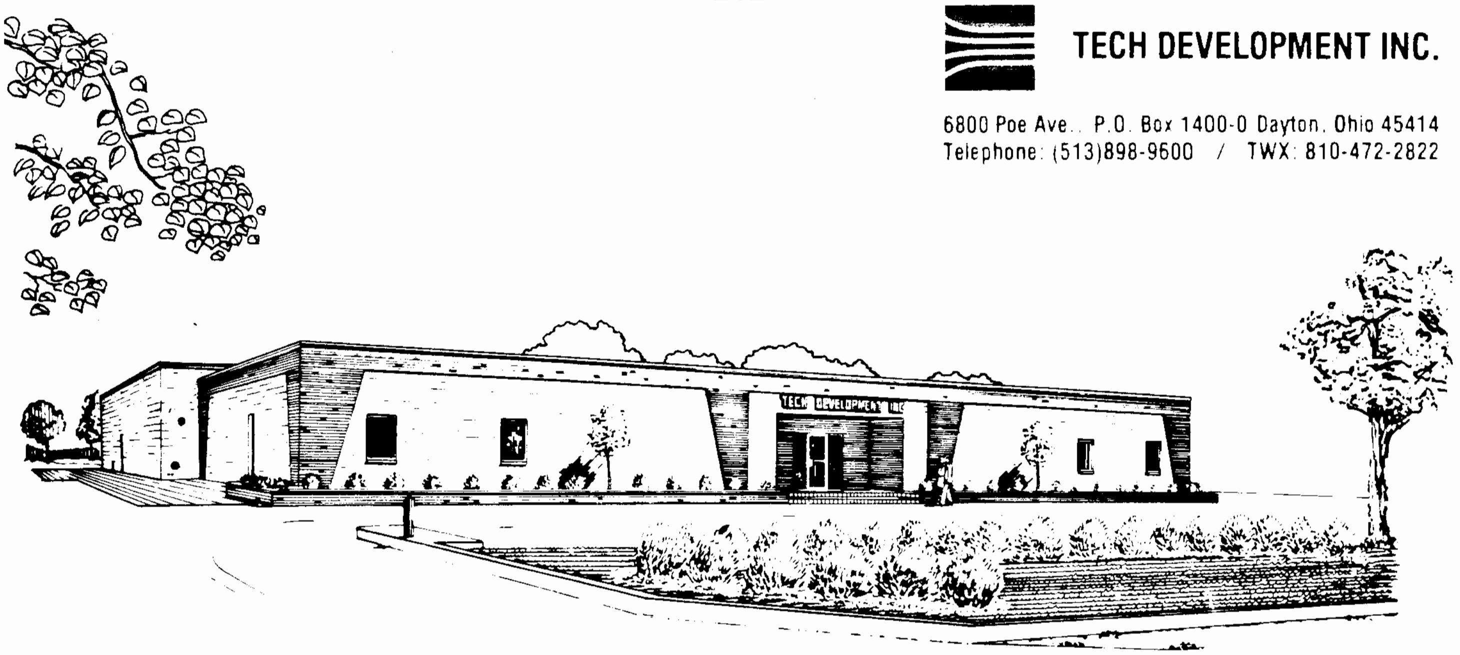


TECH DEVELOPMENT INC. has been actively engaged in research, design development and fabrication of precision mechanical and pneumatic devices since its founding in 1958. TDI has grown steadily since that time and has earned a reputation for problem solving, workmanship, quick response to customer needs and program management. Its list of customers include companies such as B.F. Goodrich, McDonnell Douglas, Boeing, Sperry Vickers, Rolls Royce and Lockheed; and governmental agencies such as the NASA, the U.S. Air Force, and the U.S. Navy.

Five of the principal market areas in which Tech Development is involved with are shown in this brochure. They are:

- Air Starter Motors
- Turbine Air Motors
- Turbomachinery Design & Production
- Aircraft Escape Slide Inflators
- Propulsion Simulators

In addition, TDI has performed precision machining services for O.E.M.'s, conducted research under subcontract on small diameter turbomachinery, and provided engineering and design support services to other companies and agencies.

This brochure contains only a sample view of the products that TDI has engineered and produced. We would welcome the opportunity to discuss how we can apply our technology to assist you with your unique design problems.

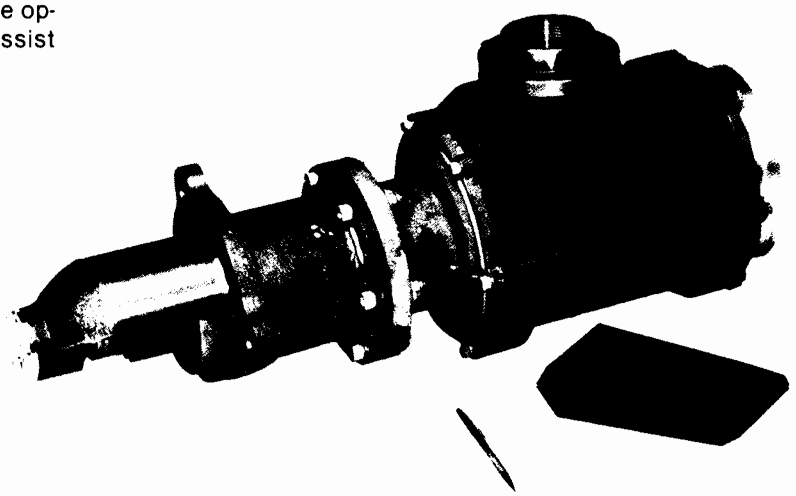
FACILITIES, EQUIPMENT & PEOPLE

- 50,000 sq. ft. new facility
- Full engineering and design staff
- Highly skilled senior model makers
- Computer time share terminal to G.E. Mark II system for engineering computations
- 4000 psig/10,000 lb. high pressure air system in laboratory
- Fully equipped model and production shops
- Quality Control and Inspection Departments per MIL-I-45208A
- Three test cells and central control room with full instrumentation
- Administrative and management staff with hands-on experience in aerospace, commercial, industrial, and governmental sectors.

Complete listings of our shop and laboratory equipment are available upon request.

AIR STARTER MOTORS ►

A new market being developed for TDI's products is the starting of large stationary diesel and carbureted engines. The Series 52A starter shown here is capable of producting 85 hp during the starting cycle. The turbine driven starters offer significant operating efficiencies over current starters in use today throughout the world. Future TDI air starters may find application in heavy duty off-highway and over-the-highway diesel powered vehicles.

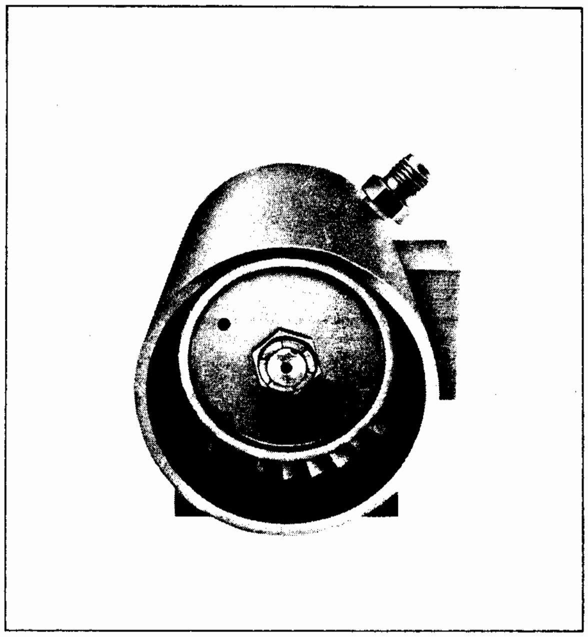


TURBINE AIR MOTOR

PRODUCT SPECIFICATION

GENERAL INFORMATION

The Model 866A Pneumatic Motor is a single-stage impulse turbine designed to produce 25 horsepower at a shaft speed of 100,000 RPM. It is driven by compressed air or nitrogen. The unit occupies an envelope of 3.0 in. by 3.9 in. by 4.3 in., providing a very compact high-output power source. Weight is only 4.1 pounds. The Model 866A requires external lubrication of its bearings and an oil mist lubricator kit is supplied with the unit. Greased packed bearings can be substituted, but the operating rpm and horsepower or running time may be reduced.

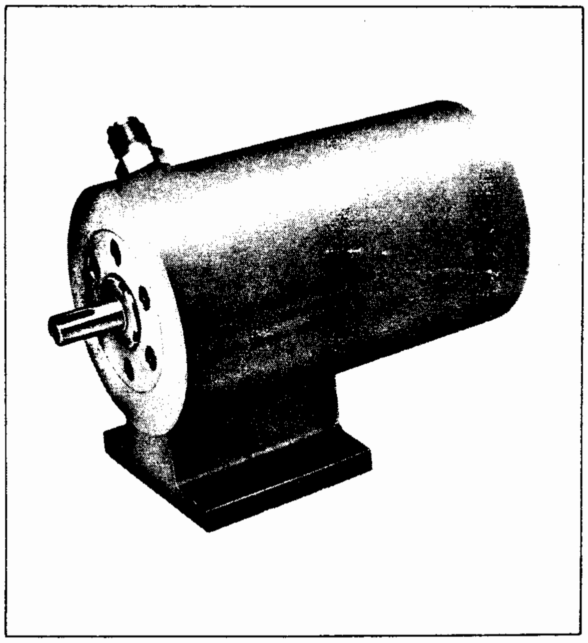


OPERATION

The curves on the reverse side give performance data. Drive must be dry and clean to avoid erosion of turbine blades and nozzles. A filter capable of eliminating particulate of 40 microns is recommended. Motor can be operated continuously in any position at speeds up to 100,000 rpm.

INSTALLATION

The drawing on the reverse side shows the assembly, including over-all installation, dimensions. Standard pad type drive gas inlet is shown; however, inlet can be designed to suit individual requirements. Face mounting provisions can be provided in place of the foot mounting shown. Contact Tech Development for specialized application engineering consultation.



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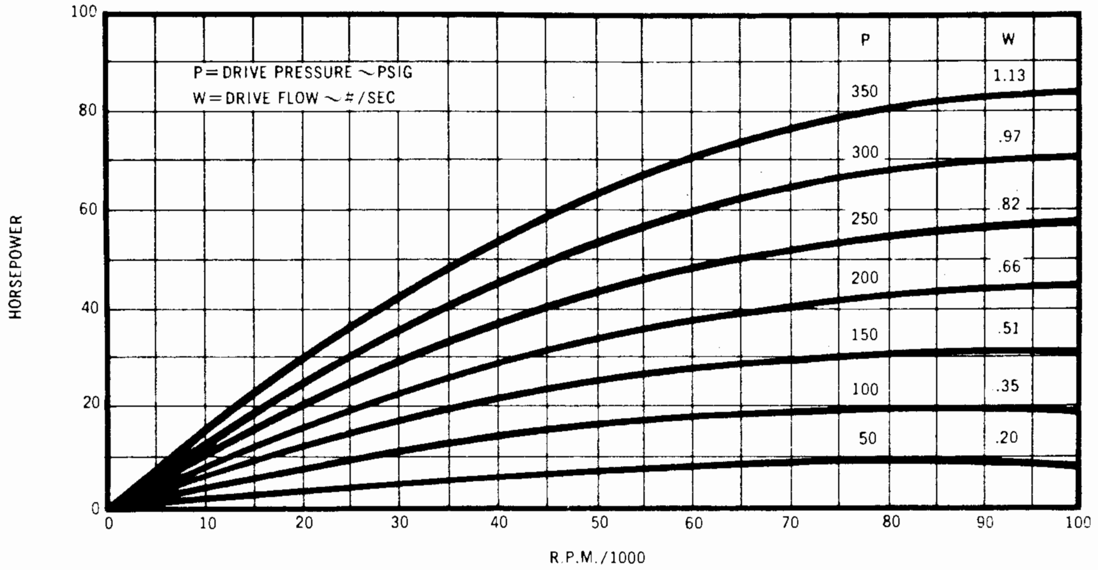
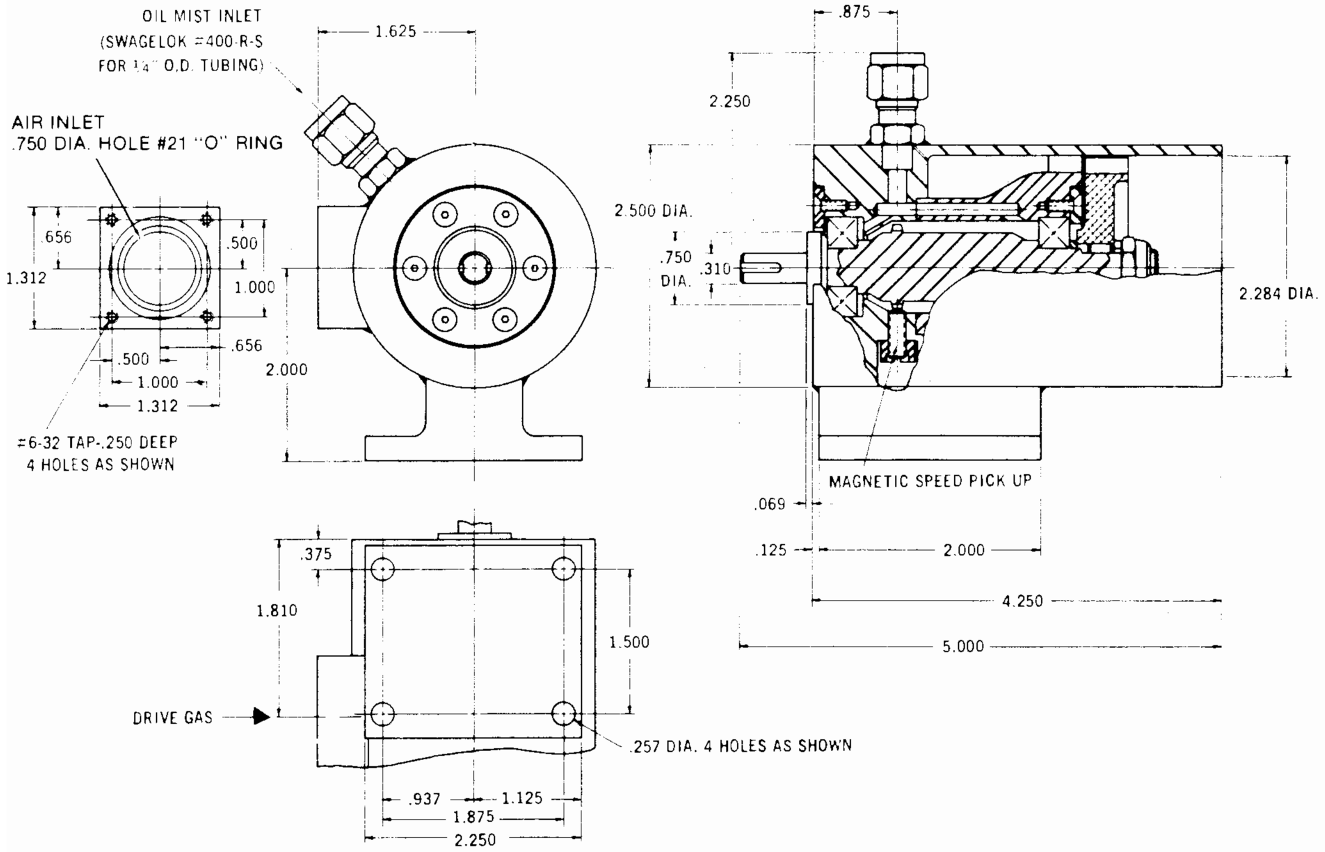
Model 866A Turbine Air Motor

Model 866A Performance Curves



Model 866A Installation Features



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TURBINE AIR MOTOR

PRODUCT SPECIFICATION

GENERAL INFORMATION

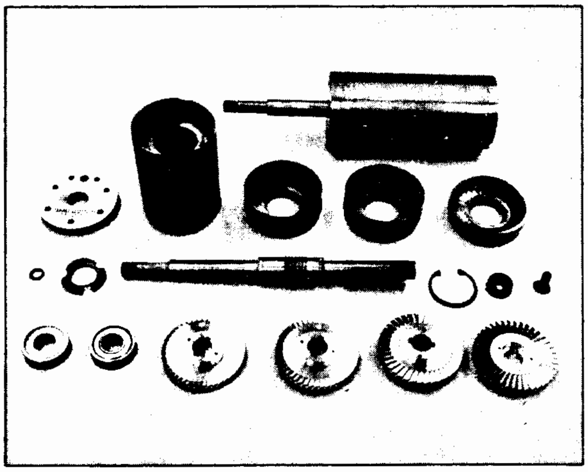
The Model 646 Pneumatic Motor is a high horsepower-to-weight-ratio prime mover designed to deliver 55 shaft horsepower at 16,000 rpm. It is based on a four-stage turbine, driven by compressed air or nitrogen directed into the first stage nozzle plenum. The four stages provide power at the desired speed without the use of gears. Unit weighs approximately 11 pounds.

OPERATION

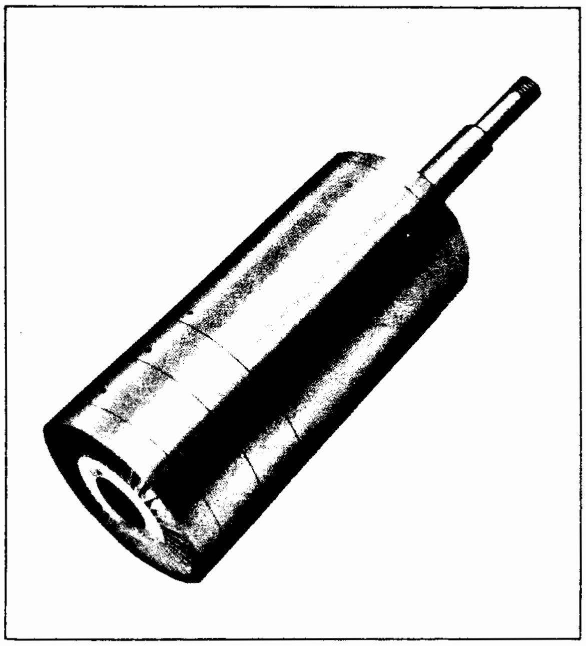
The curves on the reverse side give performance data. Driving gas must be dry and clean to avoid erosion of turbine blades and nozzles. A filter capable of eliminating particulate of 40 microns is recommended. Motor can be operated continuously in any position at speeds up to 20,000 rpm.

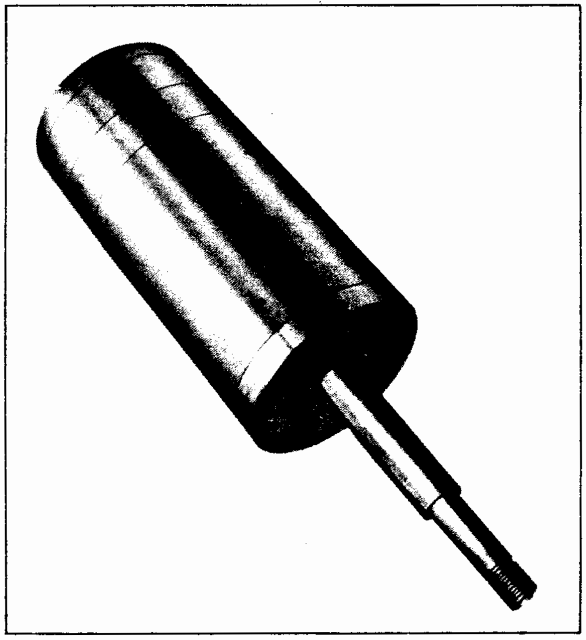
INSTALLATION

The drawing on the reverse side shows the assembly, including over-all installation, dimensions. Support should be by attaching to the 8-32 tapped holes in the front face.



MODEL 646 COMPONENT PARTS





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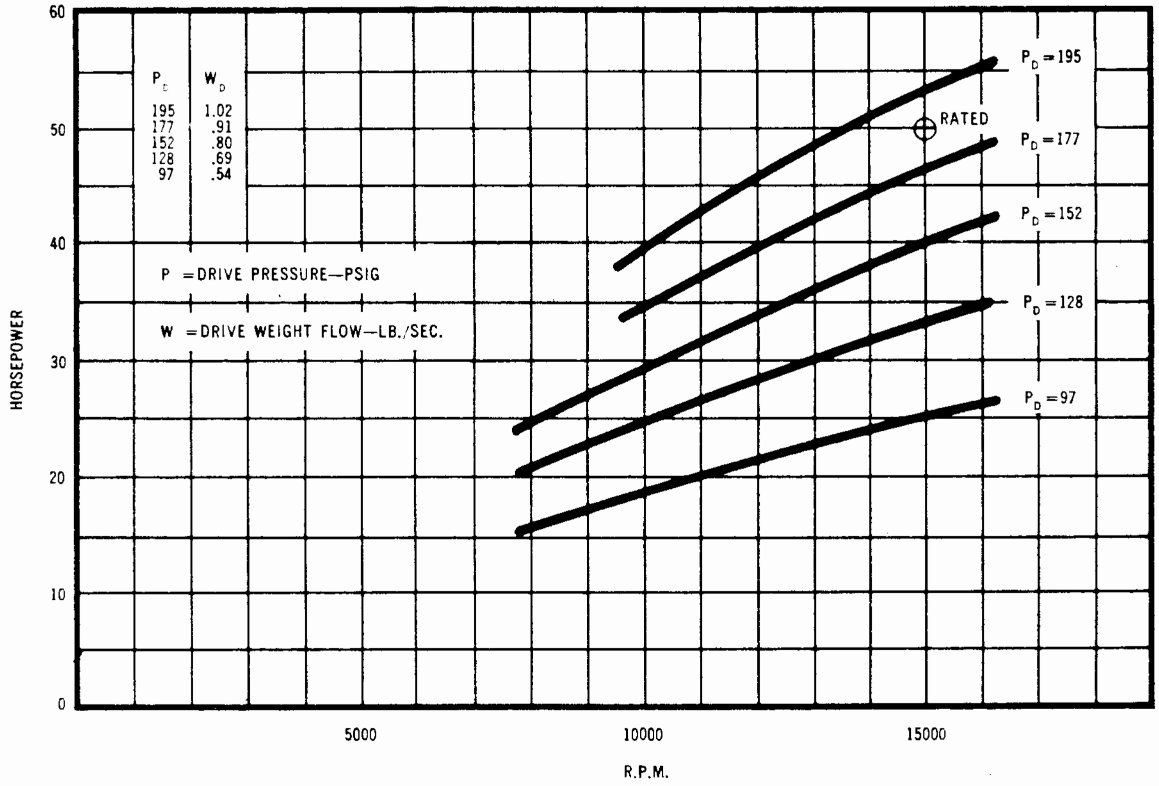
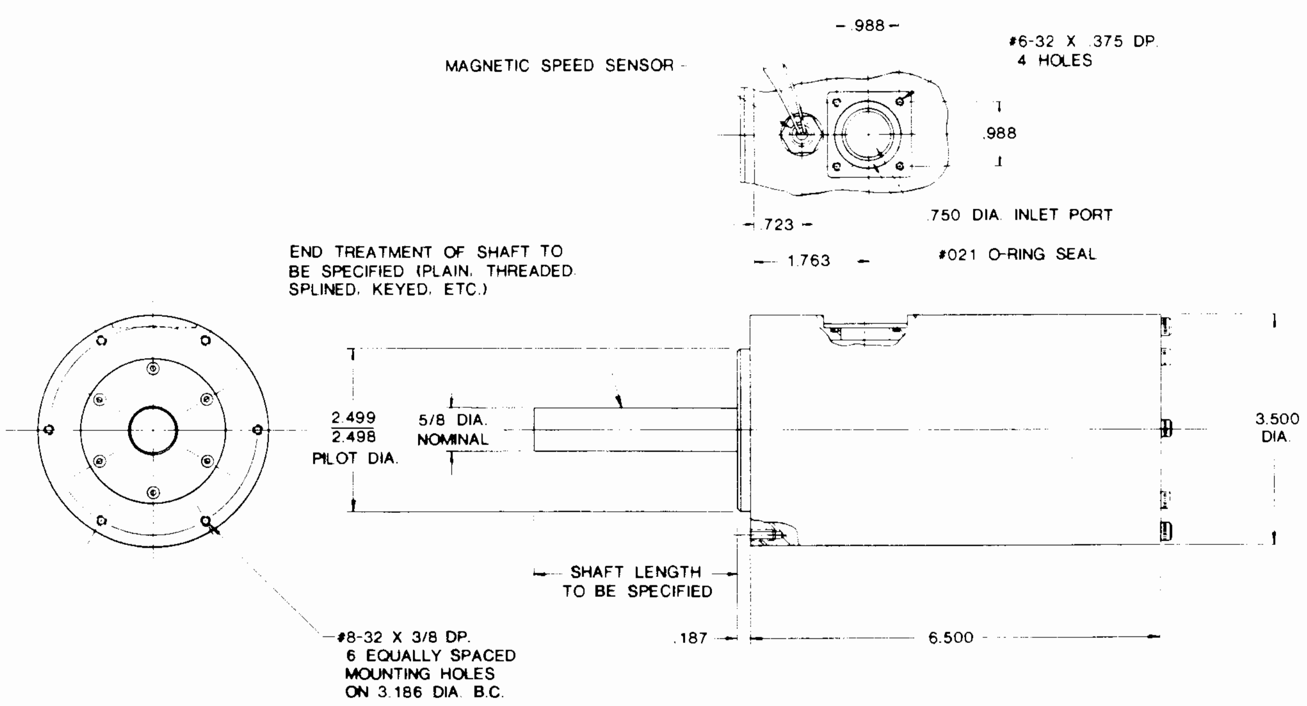
Model 646 Turbine Air Motor

Model 646 Performance Curves



Model 646 Installation Features



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AN80-022

TURBINE AIR MOTOR

PRODUCT SPECIFICATION

GENERAL INFORMATION

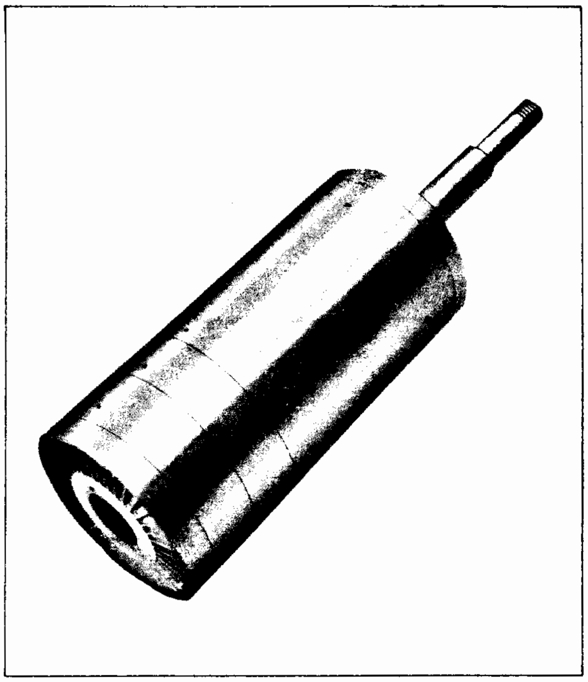
The Model 666 Pneumatic Motor is a high horsepower-to-weight-ratio prime mover designed to deliver 137 shaft horsepower at 16,000 rpm. It is based on a four-stage turbine, driven by compressed air or nitrogen directed into the first stage nozzle plenum. The four stages provide power at the desired speed without the use of gears. Unit weighs approximately 12.5 pounds.

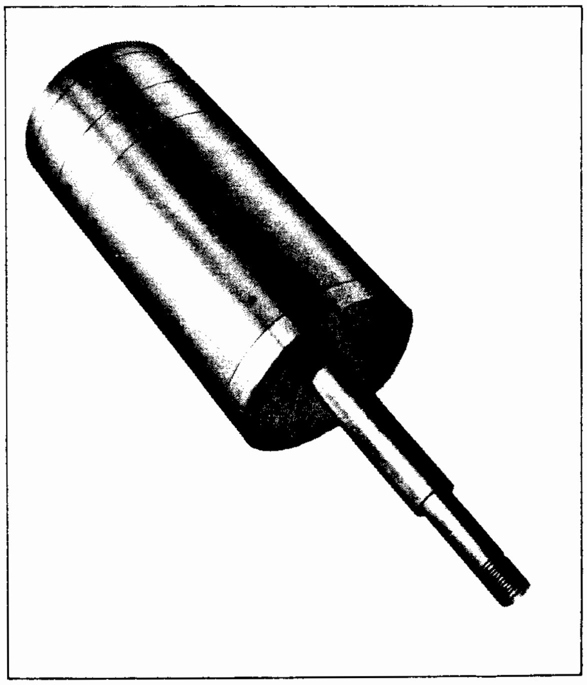
OPERATION

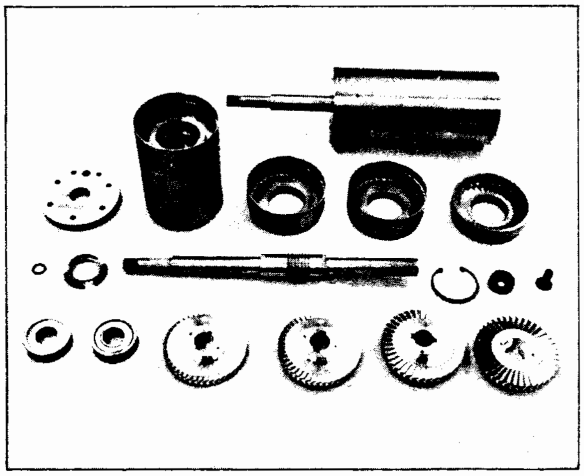
The curves on the reverse side give performance data. Driving gas must be dry and clean to avoid erosion of turbine blades and nozzles. A filter capable of eliminating particulate of 40 microns is recommended. Motor can be operated continuously in any position at speeds up to 20,000 rpm.

INSTALLATION

The drawing on the reverse side shows the assembly, including over-all installation, dimensions. Support should be by attaching to the #10 screw clearance holes in the front face.







MODEL 666 COMPONENT PARTS

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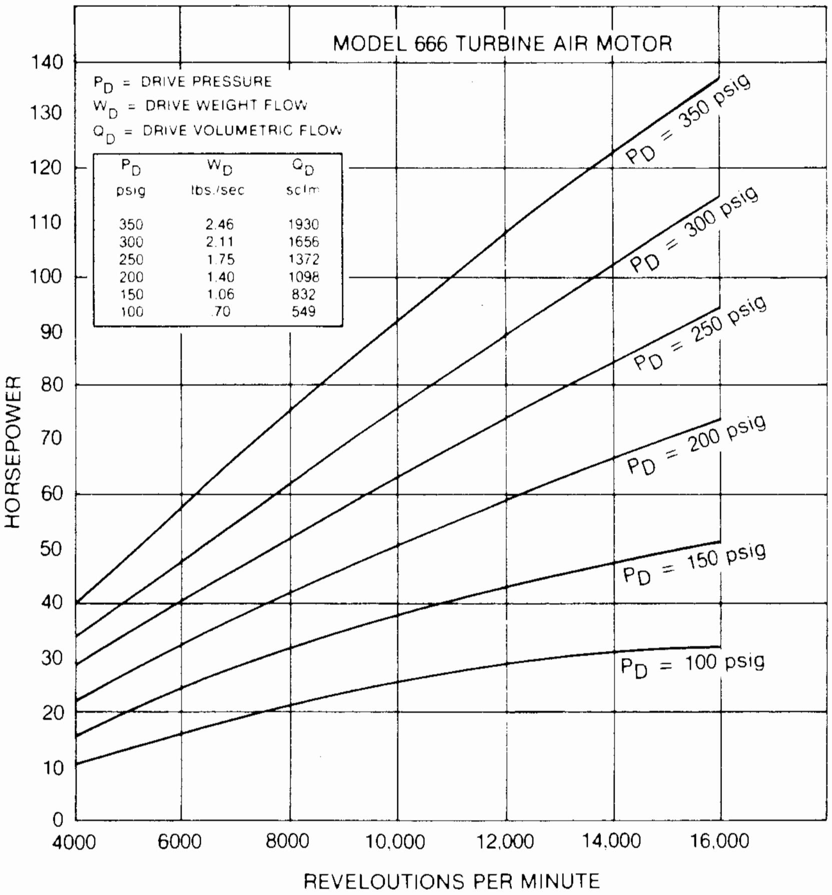
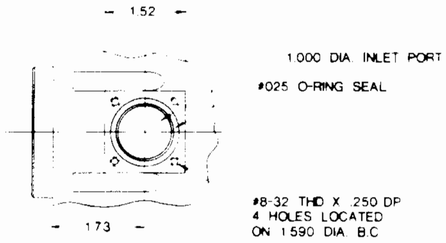
Model 666
Turbine Air Motor

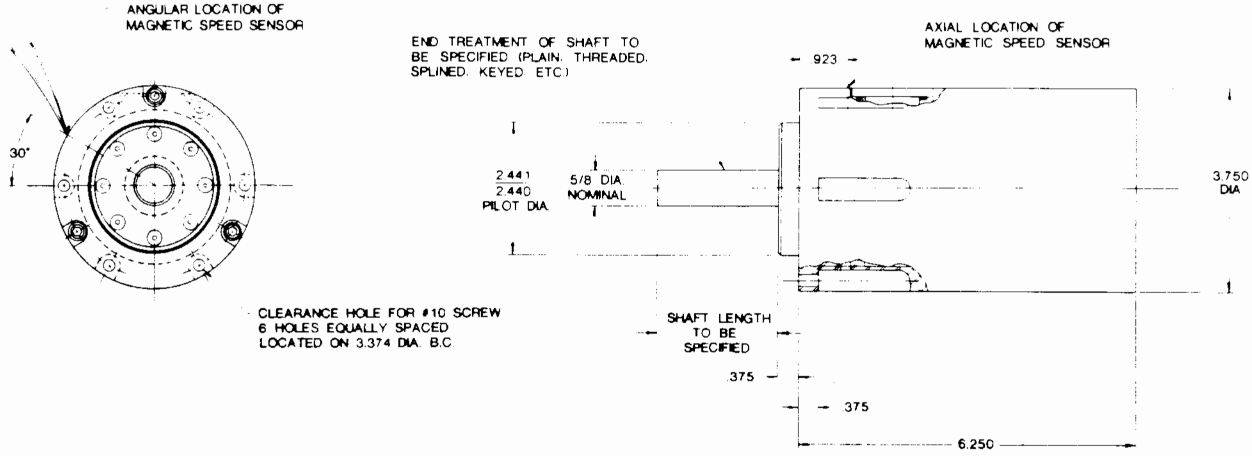
Model 666 Performance Curves



P_D psig	W_D lbs./sec	Q_D scfm
350	2.46	1930
300	2.11	1656
250	1.75	1372
200	1.40	1098
150	1.06	832
100	.70	549

Model 666 Installation Features





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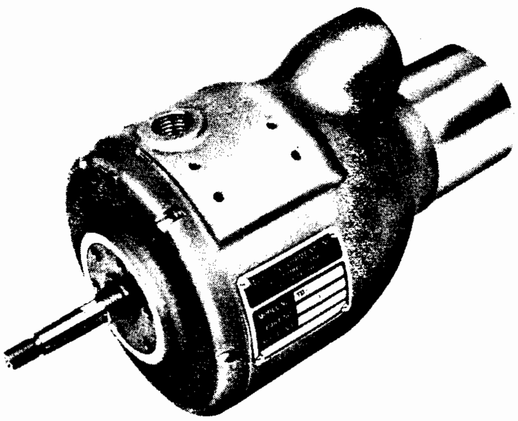
1134B TURBINE AIR MOTOR

PRODUCT SPECIFICATION

GENERAL INFORMATION

The Model 1134B turbine air motor is a 1/10 HP to 3 HP pneumatic motor well suited for a wide variety of industrial applications. It is designed to operate at the normal air pressures and flow rates usually found in most manufacturing plants. One of its principal advantages is that it does not require lubricant in the supply air as is the case with traditional vane type air motors. Likewise, it is extremely tolerant to dust and grit in the drive air. The bearings are grease packed and the life of the motor is measured in thousands of hours, however, the exact motor life would vary according to the application. An important feature of the 1134B turbine air motor is that it's output can be precisely tailored for the application by installation of a nozzle plate with the proper number of nozzles, the intended application. The nozzle plate configuration can be varied from 6 to 36 nozzles. The number is selected to fit the rpm, horsepower, drive pressure and air flow required.



OPERATION AND PERFORMANCE

The curves on the rear of this brochure show the torque and horsepower versus rpm for the 1134B-06 (6-hole nozzle plate) through the model 1134B-36 (36-hole nozzle plate). Each set of curves shows the performance varying as the air flow is increased via the addition of nozzle holes. A characteristic of turbine motors is that the air consumption remains constant for a constant drive gas pressure over the entire rpm operating range. The horsepower output of the turbine air motor is a direct function of the rpm at which the motor is allowed to run.

SUMMARY PERFORMANCE MODEL 1134B-36 AIR MOTOR (at 60 psig/134 scfm)

RPM	Power (shp)	Torque (lb · in)
0	0	18.5
10,000	2.3	14.4
20,000	3.2	10.2
30,000	2.8	6.0

INSTALLATION

The drawing on the next two pages shows the installation features and dimensions of the Model 1134B turbine air motor. The mounting of the motor in the current configuration is done via the bore on the aft portion of the motor housing. To suit individual applications, a face or foot mounting provision could be provided. The output shaft of the motor is shown with a Number 1 Morse Taper configuration. An optional straight output shaft with keyway is available. In those cases where speed monitoring is important, there is also an optional magnetic speed pickup which can be installed by Tech Development. Compressed air is fed to the motor through a 1/2" diameter NPT threaded inlet port and exhausted via a 1" diameter NPT outlet port. A silencer may be attached to the exhaust port providing it does not backpressure the air motor greater than 2 PSIG.

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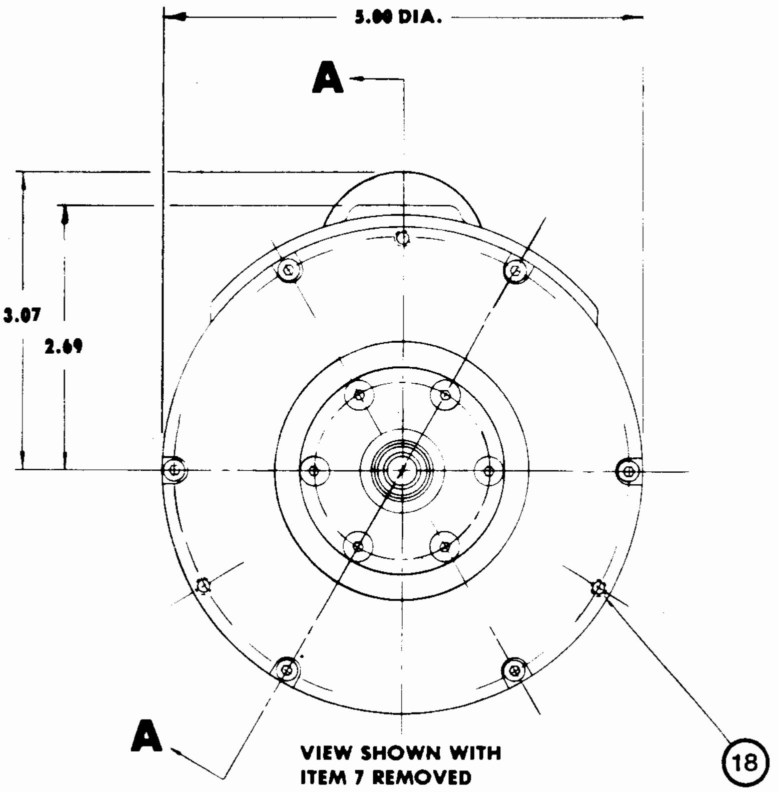
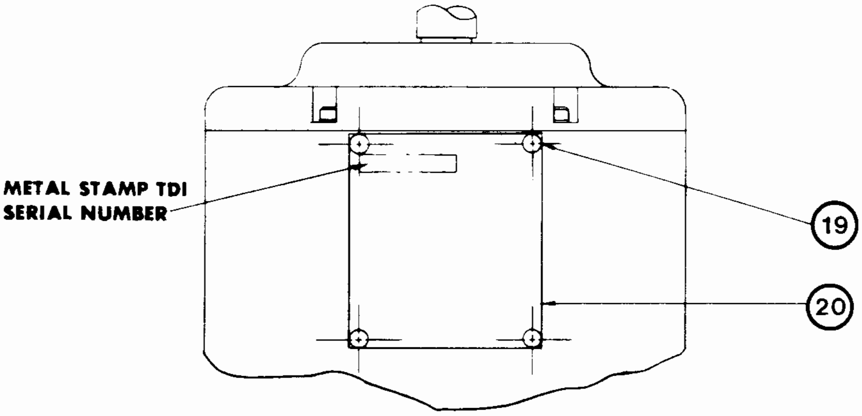
MODEL 1134B TURBINE AIR MOTOR
INSTALLATION DRAWING



VIEW SHOWN WITH ITEM 7 REMOVED



PARTS IDENTIFICATION LIST

INDEX NO.	PART NO.	PART NAME
	D-17623	AIR MOTOR ASSEMBLY
1	D-17620	HOUSING — AIR MOTOR
2	D-17621	BEARING HOUSING - AIR MOTOR
3	C-17538	SHAFT - AIR MOTOR
4	B-17539	BEARING RETAINER - AIR MOTOR
5	C-17541	NOZZLE PLATE - AIR MOTOR
6	C-17542	TURBINE ROTOR - AIR MOTOR
8	A-17635	BEARING
9	A-17628	SCREW
10	A-17629	SCREW
11	A-17548	KEY
12	A-17631	NUT
13	A-17632	"O" RING
14	A-17633	"O" RING
15	A-17634	WAVE SPRING WASHER
16	A-17540	BEARING SPACER - AIR MOTOR
17	A-17636	SHIM
18	A-17646	SET SCREW
19	A-17687	#4 × 3/16 LG. ROUND HEAD DRIVE SCREW
20		NAME PLATE

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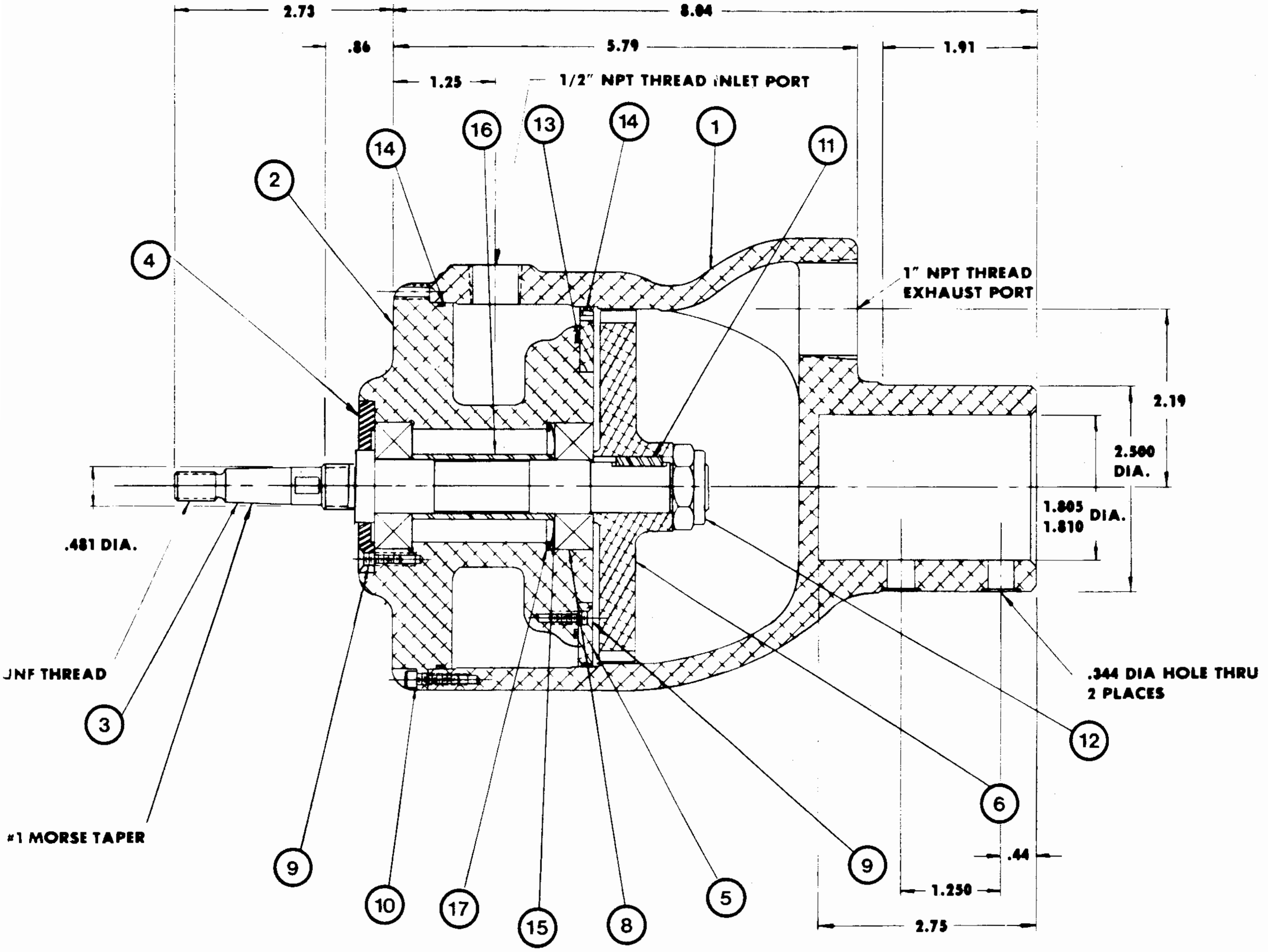

SECTION **A-A**

NOTE: All dimensions shown are in inches.

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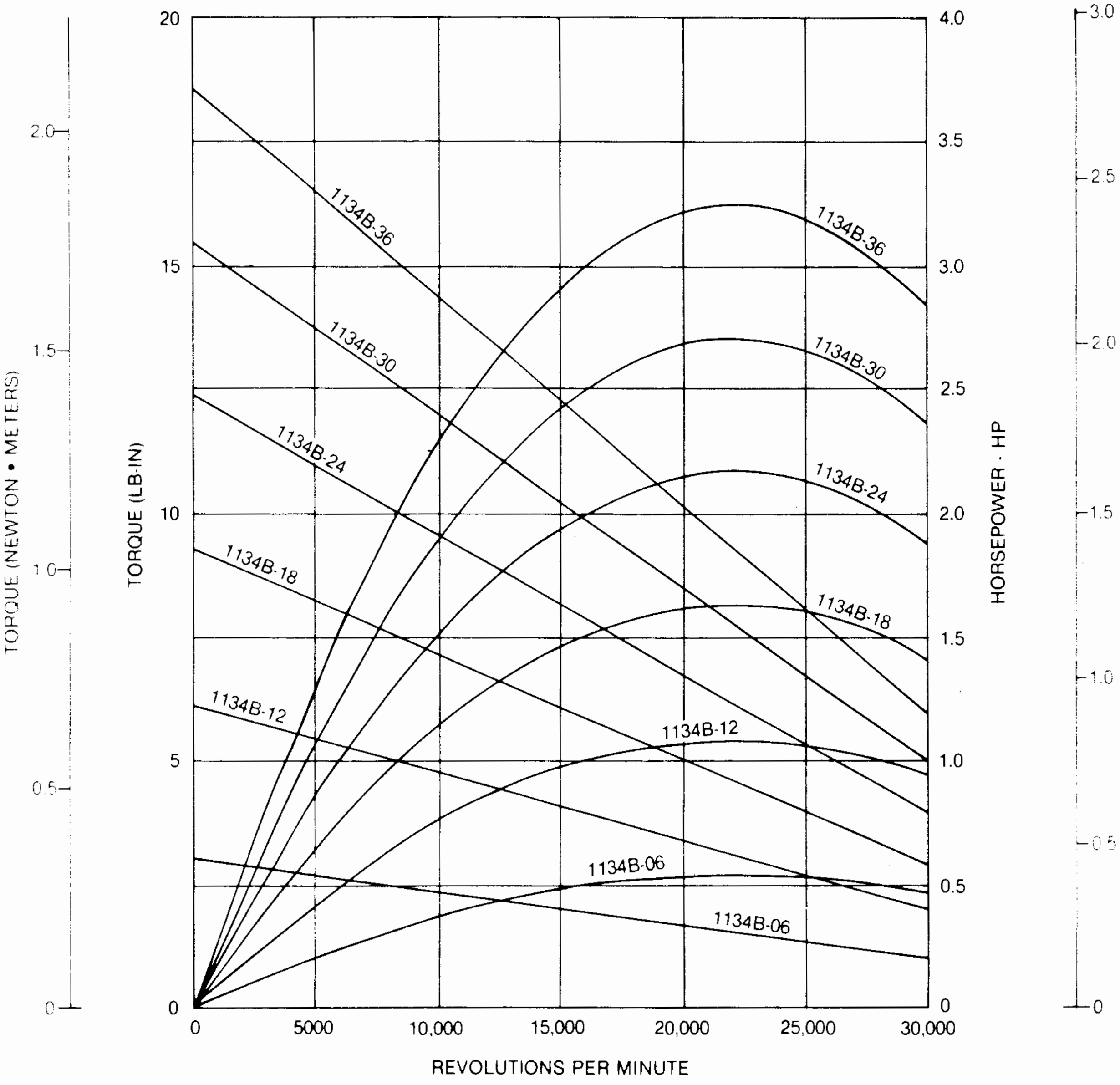
Model **1134B**
Turbine Air Motor

PERFORMANCE CHARACTERISTICS
PERFORMANCE AT 60 PSIG (70 °F) DRIVE PRESSURE*



AIR CONSUMPTION RATES**

[at 60 psig (4.1 x 10^5N/m², gauge), 70 °F (21 °C)]

Model	SCFM	M³/Min
1134B-36	134	3.8
1134B-30	112	3.2
1134B-24	90	2.6
1134B-18	67	1.9
1134B-12	45	1.3
1134B-06	23	0.7

*__NOTE:__ The curve above illustrates the performance of Model 1134B for a 60 PSIG drive pressure. This motor may be operated effectively over a range of pressures from 20 PSIG to 90 PSIG. The horsepower, torque and air consumption will vary due to these different pressures, and this performance data can be provided by Tech Development on request.

**__NOTE:__ A characteristic of turbine motors is that the air consumption remains contant for each dash (-) version over the entire RPM range for a constant pressure drive gas. For the Model 1134B, there are intermediate dash (-) versions which can be produced for O.E.M. applications which require optimized performance.

TURBINE AIR MOTOR

PRODUCT SPECIFICATION

GENERAL INFORMATION

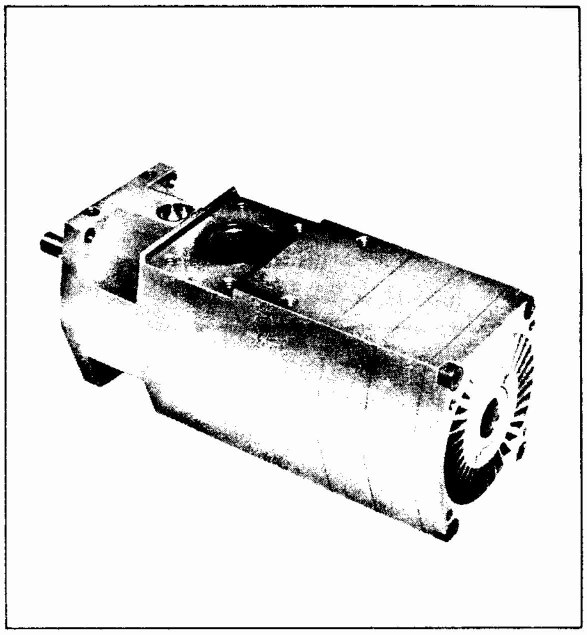
The Model 845A Pneumatic Motor is a high horsepower-to-weight-ratio prime mover designed for use wherever a large amount of power is required in a confined space. It is based on a four-stage turbine, driven by compressed air or nitrogen directed in the first nozzle plenum. The four stages provide power at the desired speed without the use of gears. Unit weighs approximately 3¼ pounds. The Model 845A has greased packed ball bearings and requires no external source of lubrication.

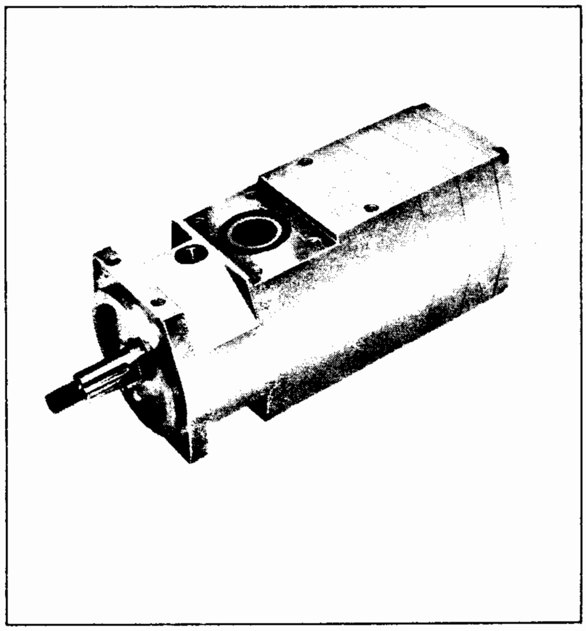
OPERATION

The curves on the reverse side give performance data. Drive must be dry and clean to avoid erosion of turbine blades and nozzles. A filter capable of eliminating particulate of 40 microns is recommended. Motor can be operated continuously in any position at speeds up to 30,000 rpm.

INSTALLATION

The drawing on the reverse side shows the assembly, including over-all installation dimensions. Standard pad type drive gas inlet is shown; however, inlet can be designed to suit individual requirements.





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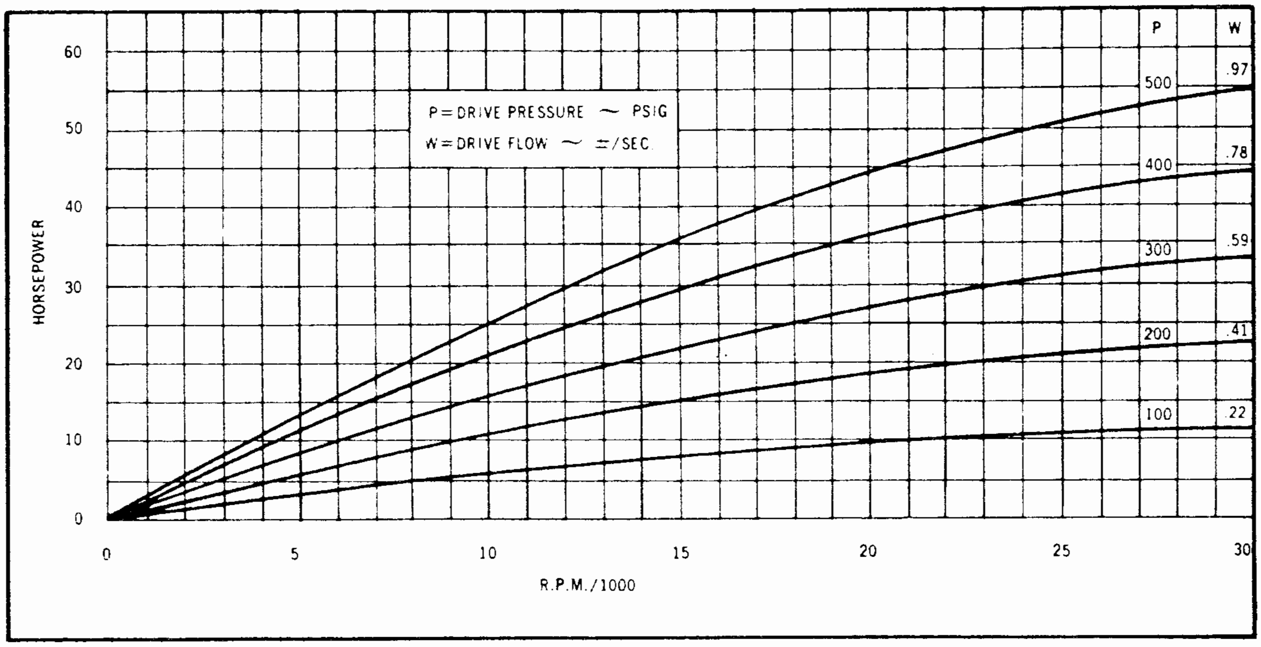
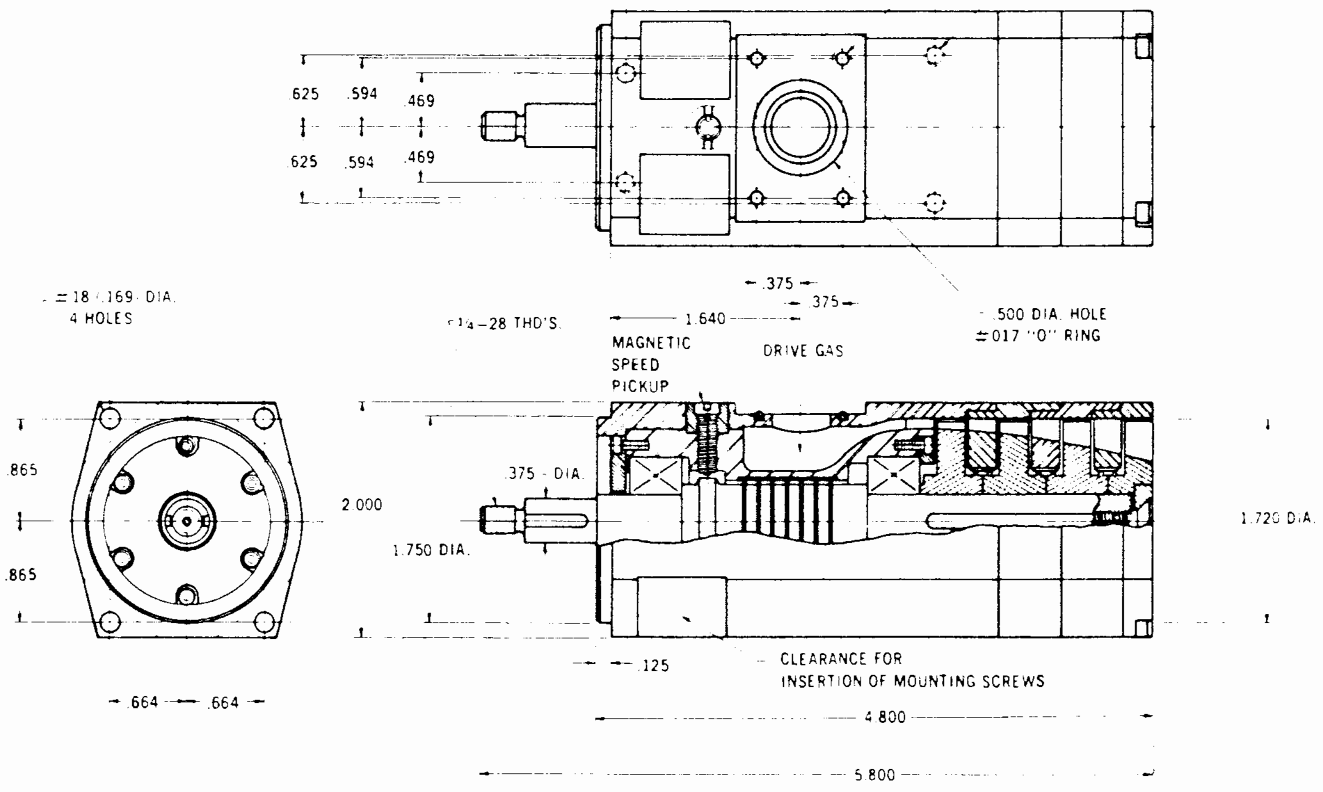
Model 845A
Turbine Air Motor

Model 845A Performance Curves



Model 845A Installation Features



Litho in U.S.A. 3-1980 Tech Development Inc.

AN80-018

Quasiturbine Pneumatic Engine

(For the steam engine, see http://quasiturbine.promci.qc.ca/QTVapeur.html)
Since the Quasiturbine is a pure expansion engine
(which the Wankel is not, neither most of other rotary engines),
it is well suitable as compressed fluid engine - Air engine or air motor.

From the basic 200cc per revolution engine bloc,
a compressed air prototype has been built making use of 2 parallel expansion circuits
of 200cc per revolution each, for a total of about 14 cubic feet intake per minute at 1000 RPM.

The pneumatic engine does not show any vibration on the shaft.
**As an example, a chainsaw with a pneumatic engine (running from pressure air bottle regulated to 300 psi)
allows for a non combustible "all condition" running unit for the fireman and national safety teams.
It does run in heavy smoke or under water as well. Exhaust can even be respirated by the fireman !
A must for all civil defence organization ...
(See the old 1998 pneumatic chainsaw video on the website entry page)**

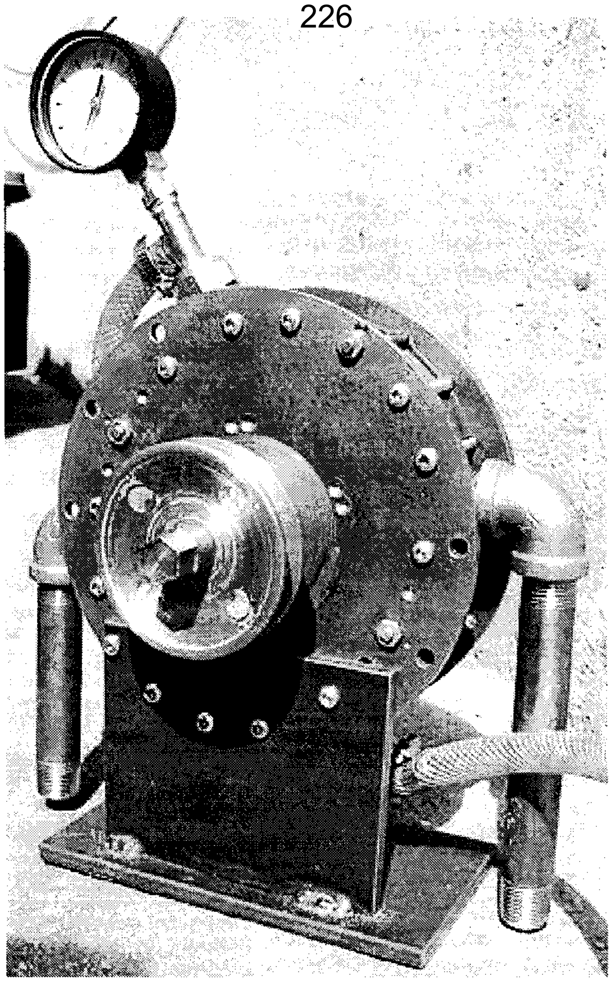
REMARK ON PNEUMATIC SYSTEM EFFICIENCY

An high efficiency pneumatic motor does not guaranty the high efficiency of the entire pneumatic system.
All gas heat up during compression and cool down during relaxation.
The cooling effect must not be under-estimate. As an example, a typical 200 bar (atm.) cylinder
empty adiabatically (without thermalization to ambient temperature) gives at the end an air so cold
that its volume is then a 1/4 of that of the air once back to the ambient temperature (isothermal relaxation).
In those temperature conditions at the entrance of a pneumatic motor, the efficiency is catastrophically low
and the lubricant solidified, increasing considerably the internal engine friction...
Generally, the reversibility of the compression - relaxation cycle reduces with an increase in pressure,
which favours for high efficiency consideration the use of the lowest design pressure possible.
The measurement of the exhaust temperature gives generally a good indication of the efficiency,
since the minimum of energy lost into the environment correspond to
an exhaust temperature equal (neither inferior, nor superior) to the ambient temperature.
This condition can be achieve by a slight heating (solar) of the gas before its entry into the pneumatic motor.
Since the Quasiturbine rotates from pressure as low as 1/10 of atmosphere (bar) (one psi !),
one understand why the Quasiturbine is so well adapted to high efficiency system...

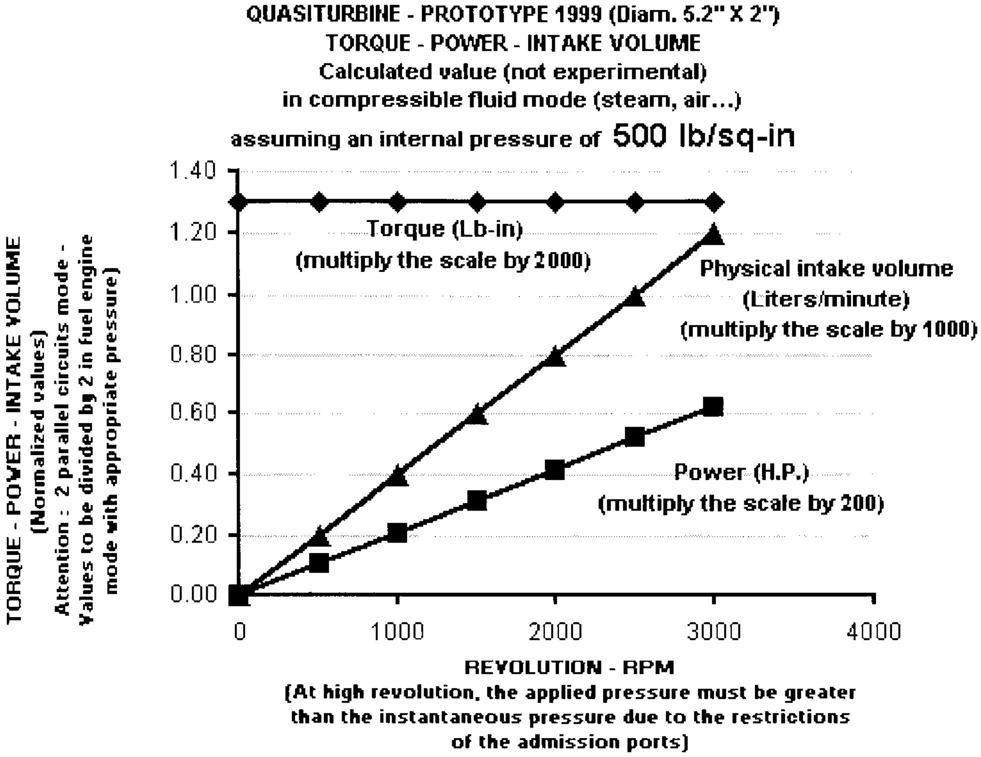
**See Quasiturbine Hydraulic Motor at:
Quasiturbine.promci.qc.ca/QTHydraulique.html**

See also:
Quasiturbine - Comparative efficiency with other engines

http://quasiturbine.promci.qc.ca/QTEfficaciteComparative.html



Quasiturbine pneumatic-steam model QT50SC (Without carriage)
Usable with intake sustained pressure as low as 20 to 50 psi!



Quasiturbine pneumatic-steam model QT50AC (With carriages)
Assuming a pressure differential of 500 lb/sq.in., this graph gives for each **rpm** :
the engine torque, the power and the geometric intake flow.

Those result can be scaled linearly for other pressure differentials.
Usable with intake sustained pressure as low as 20 to 50 psi!

THERMO-PNEUMATIC NITROGEN CONCEPT

Liquid nitrogen is somewhat a reject of the oxygen distillation process, and is consequently relatively affordable.
To avoid energy consumption in the high temperature latent heat (like the water evaporation for example),
and better invest this energy in an extreme overheating, which increases the thermodynamic efficiency of the cycle,
we propose a thermo-pneumatic open cycle, making use of a nitrogen evaporateur
which can be the Quasiturbine itself (which then act as a "flash steam generator").
See http://quasiturbine.promci.qc.ca/QTVapeur.html)
followed or not by an overheater (or overheating the Quasiturbine itself).

The world of new ecological energy often consider sources 2 orders of magnitude under the petroleum.
Assuming that an ambient temperature heat source is always available for free,
a gallon of liquid nitrogen contains only 10 to15 times less mechanical energy than a gallon of gasoline, and it is zero pollution !
[Specific energy greater than 110 W-h/kg-LN2 (90 W-h/l-LN2 or 400 kJ/kg-LN2)
without relying on isothermal expanders (which double the energy output).
Gasoline mechanical energy is around 1 third (18% in transportation) of 9600 W-h/liter.
Best lead batteries have ~30 W-h/liter-lead]
(liquid nitrogen is pure mechanical energy, while gasoline is 1/3 mechanical, 2/3 thermal).
This high performance cycle is specially simple to built, non polluant, and appear well suitable for mobile units.
It does also fit very well the pure thermal sources, like the solar energy thermal conversion stations.
This concept also allow to conceive a working cycle in which the heat quantity given to the liquid nitrogen
is such that the exhaust temperature after expansion is equal to the ambient temperature !
(See also the CRYOCAR zero pollution using liquid nitrogen, form the University of Washington state:
http://www.aa.washington.edu/AERP/CRYOCAR/HomePage/Index.htm)

Comme le rendement croît rapidement avec la surchauffe, nous proposons d'utiliser en plus
un petit brûleur au propane par exemple, pour surchauffer l'azote gazeux (et par conséquent la Quasiturbine elle-même),
de sorte que les températures d'échappements après le refroidissement adiabatique soient de l'ordre de 100 degrés Celsius ou plus.
Ce régime permet plusieurs avantages :
- Accroît le rendement de 50% ou plus.
- Bien que les échappements d'azote soit sans humidité pour le premier étage d'échangeur de l'évaporateur, la condensation de l'humidité pose problème dans les étages subséquents si réchauffés à l'air ambiant, ce que l'usage d'un brûleur supprime compètement.
- Remarquer que l'énergie du brûleur se retrouve dans les échappements chauds d'azote, et que cette énergie est récupérée par la vaporisation de l'azote liquide, l'apport net est donc transitoire et minime en continu.
- Le brûleur est de toutes façons requis abord des véhicules en région nordique pour réchauffer l'habitacle!

La chaleur de vaporisation et de réchauffement de l'azote liquide pourra ultérieurement être récupérée
en remplaçant l'évaporateur par une Quasiturbine-Stirling montée cote-à cote sur le même arbre:
http://quasiturbine.promci.qc.ca/QTStirling.html

Note on the efficiency

Comme pour la vapeur, l'efficacité du cycle est fonction de la capacité à réaliser une surchauffe du gaz.
Le refroidissement dans une bouteille de gaz pressurisée est initialement considérable,
ce qui réduit beaucoup la pression de la bouteille, mais pire refroidit le gaz qui augmente de densité et se consomme alors trop rapidement.

Si le milieu ambiant peut fournir de la chaleur de chauffe gratuite tant mieux, mais la surchauffe impose généralement un brûleur (hybride).

Un agencement efficace requiert donc un échangeur (pour réchauffer à la température ambiante) à la sortie de la bouteille,
suivit d'un surchauffeur du gaz (propane ou autre) juste avant l'entrée dans le moteur à détente (Quasiturbine).
La disposition à privilégier serait donc un brûleur en partie inférieur juste en dessous du surchauffeur,
sur lequel la bouteille pourrait elle même se trouver pour bénéficier d'une réchauffe résiduelle,
et finalement l'échangeur (pour réchauffer à la température ambiante) coiffant le tout...

Les gaz d'échappement du moteur dépourvus d'humidité gagnent à être injectés au niveau supérieur du surchauffeur pour éviter le givre.

La réversibilité d'un système de stockage pneumatique se détériore avec la pression maximum choisie,
à moins de conserver dans le réservoir la chaleur des gaz au moment de la compression (stockage courte durée inférieur à 10 bar - 150 lb/po^2).

Quasiturbine Pneumatic and Fuel cell : A perfect Match (using liquid nitrogen) !

See : http://quasiturbine.promci.qc.ca/QTPileCombustible.html

A Thermo-Pneumatic Quasiturbine Locomotive

(with addendum on subway operation)

See : http://quasiturbine.promci.qc.ca/QTPneuLocoValen030908.html

A project intended to make a **demonstration liquid nitrogen motorcycle**
is in planning at the Cegep de Rimouski, Québec (projet temporairement ? suspendu au printemps 2002)
Concours Force Avenir http://quasiturbine.promci.qc.ca/QTRimous0203.html

To know more, see the technical document at the section :
Why is the Quasiturbine revolutionizing the use of steam and solar energy ?
http://quasiturbine.promci.qc.ca/QTvapeurPourquoiE.html

Return to main menu

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US006164263A

United States Patent [19]

Saint-Hilaire et al.

[11] **Patent Number: 6,164,263**

[45] **Date of Patent: Dec. 26, 2000**

[54] **QUASITURBINE ZERO VIBRATION-CONTINUOUS COMBUSTION ROTARY ENGINE COMPRESSOR OR PUMP**

[76] Inventors: **Roxan Saint-Hilaire**; **Ylian Saint-Hilaire**; **Gilles Saint-Hilaire**; **Francoise Saint-Hilaire**, all of Condo 2804, 3535 Papineau, Montréal, QC, Canada, H2K 4J9

[21] Appl. No.: **08/982,515**

[22] Filed: **Dec. 2, 1997**

[51] **Int. Cl.**^{7} **F02B 53/00**

[52] **U.S. Cl.** **123/241**; 418/270

[58] **Field of Search** 123/241; 418/270

[56] **References Cited**

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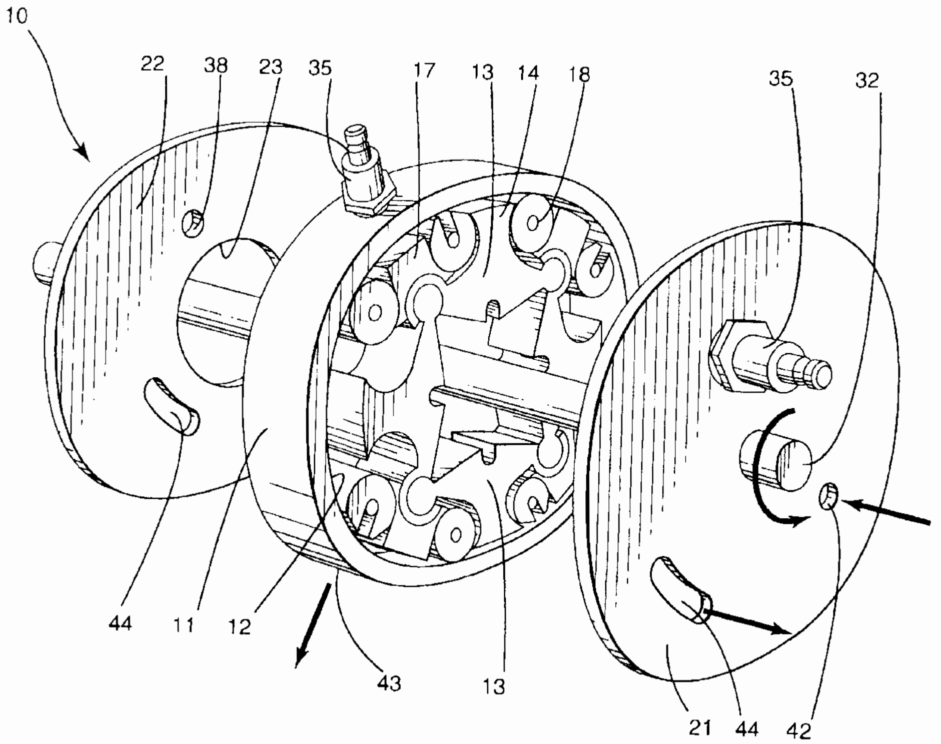
Primary Examiner—Michael Koczo

[57] **ABSTRACT**

While most rotary engines use the principle of volume variation between a curve and a moving cord of fixed length, this new engine concept uses a four degrees of freedom X, Y, θ, Φ rotor, confined inside an internal housing contour, and does not require a central shaft or support. The invention is an assembly of four carriages supporting the pivots of four pivoting blades forming a variable-shape rotor. This rotor rolls just like a roller bearing on the surface of an housing internal contour wall shaped like a skating rink. During the rotation, the rotor pivoting blades align alternatively in a lozenge and a square configuration. All ports are radial in the housing and/or axial on the lateral side covers. Since the compression and expansion strokes start and end simultaneously, an ignition flame transfer slot is used to maintain a continuous combustion while four strokes are completed in every rotation. A central shaft is not needed for the engine to operate, but can be added and driven by the blades, through a mechanical arms coupling. The device incorporates few parts, does not need a crankshaft or a flywheel, and can be made strong enough to meet the criteria of photo-detonation and direct hydrogen combustion.

21 Claims, 2 Drawing Sheets



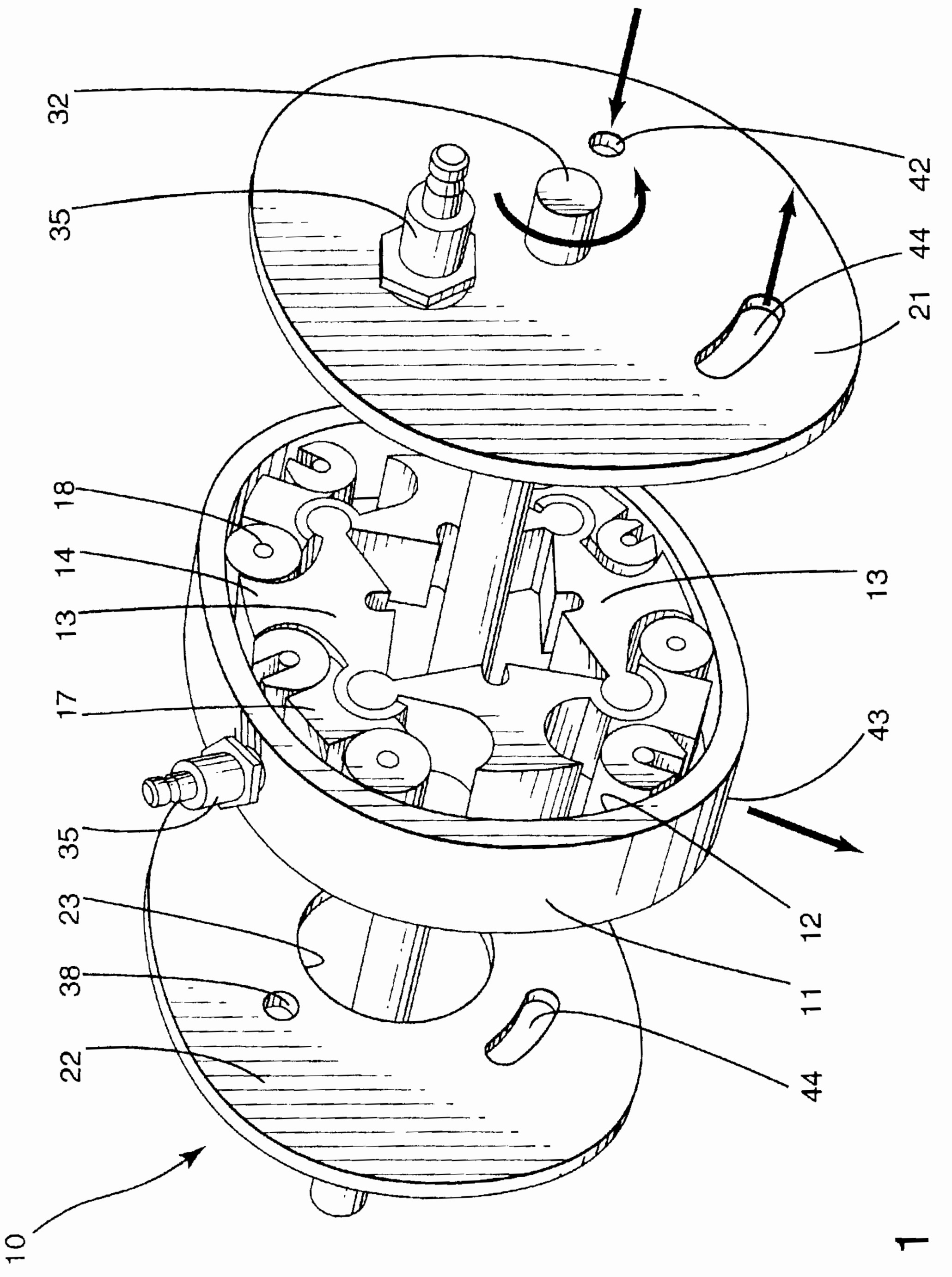


FIGURE 1

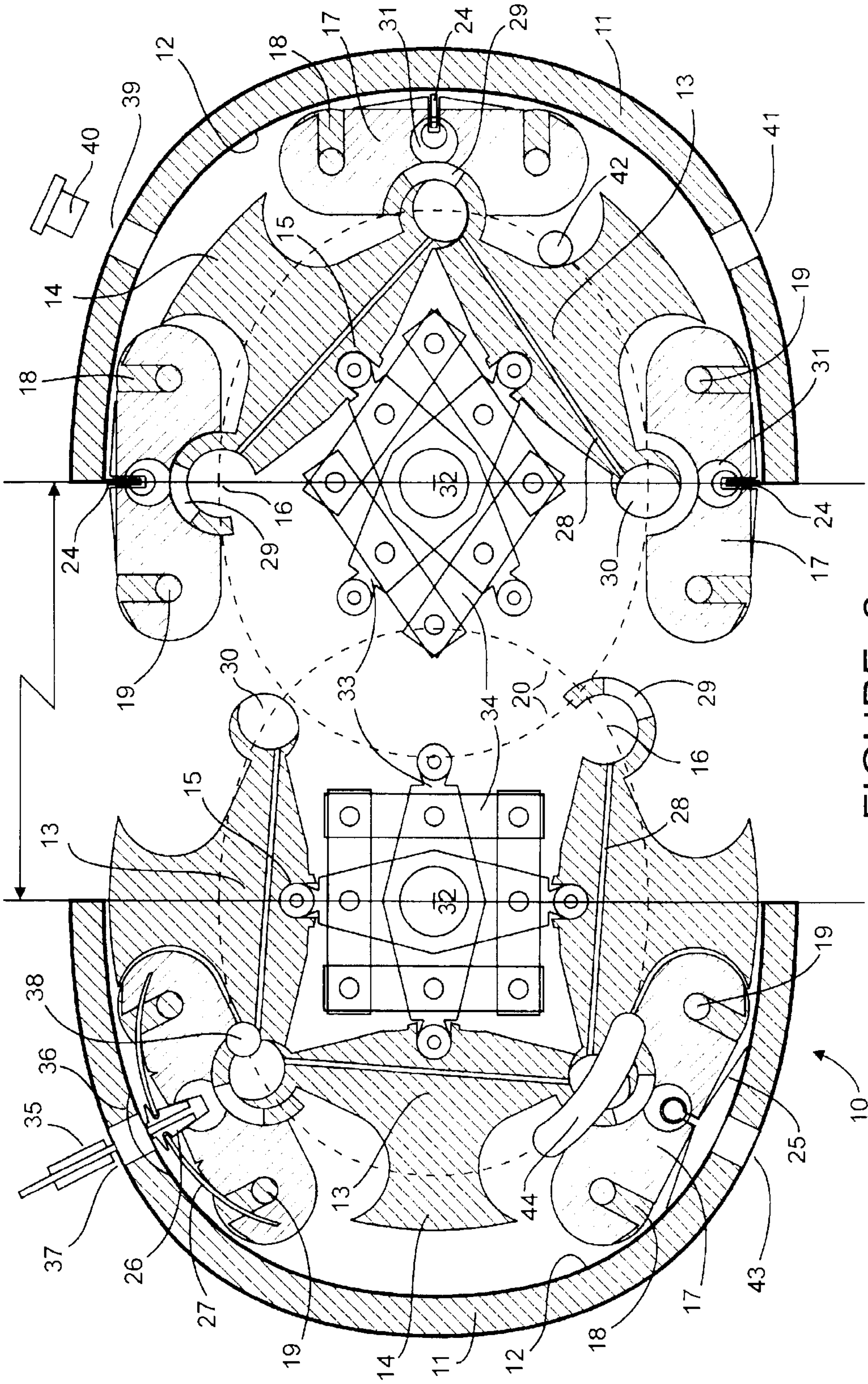


FIGURE 2

QUASITURBINE ZERO VIBRATION-CONTINUOUS COMBUSTION ROTARY ENGINE COMPRESSOR OR PUMP

FIELD OF THE INVENTION

This invention relates generally to internal combustion engines and relates specifically to a rotary internal combustion engine having a four degrees of freedom rotor, confined into a calculated housing internal contour wall. As a perfectly balance device without crankshaft, this invention is a true rotary engine, by opposition to rotary piston engine. This device also relates to compressors, and pressure or vacuum pumps.

DESCRIPTION OF THE RELATED ART

Many rotary engine concepts have been proposed including a pressure energy converter, rotary engine or compressor as in U.S. Pat. Nos. 4,068,985, 3,996,899; a rotary disk engine as in U.S. Pat. No. 5,404,850; a rotary planetary motion engine as in U.S. Pat. No. 5,399,078; a rotary detonation engine as in U.S. Pat. No. 4,741,154; a rotary combustion engine as in DE Pat. No. 2,448,828, U.S. Pat. Nos. 3,933,131, 4,548,171, 5,036,809; the Wankel type engine as in U.S. Pat. Nos. 3,228,183, 4,308,002, 5,305,721, and a continuous combustion engine as in U.S. Pat. No. 3,996,899. Most rotary engines, and particularly the Wankel and those described in U.S. Pat. Nos. 3,442,257, 3,614,277, 4,144,866, 4,434,757, DE Pat. No. 3,027,208 are based on the principle of volume variation between a curve and a moving cord of fixed length as a sliding single piston-object. This invention does not use this principle, since the housing contour wall has four zones of maximum curvature, and the maximum volume as well as the compressed volume, are both located in a minimum curvature area.

OBJECTS AND SUMMARY OF THE INVENTION

The object of this invention is to provide a new engine concept making use of a four degrees of freedom rotor, confined inside an internal housing contour wall, constituting an hybrid piston-turbine engine where the rotor acts alternatively and similarly as a compressor turbine and a power turbine, unifying in one, both of the turbines in a conventional gas turbine engine.

An other object of this invention is to provide a low noise, perfectly balanced, zero vibration, low rpm engine, making use of a more efficient and less NO_x productive asymmetric pressure cycle, giving less time to compression and exhaust stroke, and allowing more time and volume to the intake and combustion stroke.

A further object of this invention is to provide a fast accelerating, zero dead time engine, and to provide an engine almost universal in relation to energy sources, which can run efficiently on pneumatic, steam, hydraulic, liquid and gas fuel internal combustion, and due to its short pressure peak and cold intake area characteristics, is as well suitable for photo-detonation mode and pure hydrogen fuel combustion.

An other further object of this invention is to provide a high weight and volume density engine, compressor or pump, without need of any valve, check valve or obstruction, and with neither a crankshaft or a flywheel.

In order to achieve those objects, the present invention uses a four degrees of freedom rotor X, Y, θ, Φ, confined into a calculated housing internal contour wall, which does not require any central shaft or support for most applications. This concept has an optimum efficiency like the piston, because the maximum expansion volume at the end of each stroke is exactly equal to the volume generated by the movement of the tangential surface of push over a rotation.

The rotor is composed of four inter-linked pivoting blades, the pivoted ends of which are supported by a set of four carriages, free to rock on those same pivots. The assembly of the four blades and four carriages forms the rotor which is confined within the housing internal contour wall. Two plane side covers close the engine end. Intake, sparkplug and exhaust ports are made either radial in the housing, or axial in the side covers, or both.

Sealing with the side covers is effected by a system of linear and pellet type seals in contact with the plane side covers, and a spring loaded housing contour seal (apex) sitting on each carriage located in-between its set of wheels, and always perpendicular to the housing contour wall. The chamber is defined by two successive contour seals, and extend between the housing contour wall, and the related pivoting blade.

Rotation of the rotor bring successively the pivoting blades farther and closer of the housing contour wall, thus producing the compression needed by the engine, with possibility of very high compression ratio. Since there are four pivoting blades simultaneously involved in the four strokes cycle, this engine fires four times every revolution, with no dead time. The central engine area is empty, but can have a central shaft, linked to the four pivoting blades, or hold other devices such as an electric generator, a jet blades, a blower or a pump.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the invention will be readily apparent when considered in reference to the accompanying drawings wherein:

FIG. **1** is an exploded perspective view of a rotary internal combustion engine according to the present invention (seals not shown);

FIG. **2** is a longitudinal blow up sectional view for two different rotor angle positions, showing a square blades rotation arrangement on the left, and a lozenge arrangement on the right.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, an exemplary rotary internal combustion engine according to the present invention is shown and is designated generally by reference numeral **10**. The rotary engine **10** includes a housing **11** with a particular internal contour wall **12** and two lateral plane covers, containing a rotor composed of four pivoting blades **13** and four rocking carriages **17** and wheel **18**. Each pivoting blade **13** has a filler tip **14** and a traction slot **15**, and their two ends pivots **16** sit on their respective rocking carriages **17**.

The basic geometry of the rotor is shown on the FIG. **2** blow up, for two different rotor angle positions. The rotor is composed of four (one more blade **13** is shown due to blow up) pivoting blades **13** playing a similar role as the pistons or turbine blades, one end of each pivoting blade having a hook pivot **16** and the other end a cylinder pivot **16**. Each pivot **16** sits into one of the four rocking carriages **17** (one more carriage **17** is shown due to blow up). Each carriage **17** is free to rotate around the same pivot **16** in such a way as to be continuously and precisely in contact with the housing contour **12**. Each rocking carriage **17** carries a housing contour seal of one of different design **24, 25, 26** midway between the wheel axes **19**. The chamber is defined by two successive contour seals **24** or **25** or **26**, and extends between the housing contour wall **12**, and the related pivoting blade **13**. There are four variable volume chambers forming two quasi-independent consecutive circuits, each producing a compression and an expansion stroke, which start and end simultaneously. In the four stroke engine operation, the first circuit is used to compress and to expand after combustion, the next circuit is used to expel the exhaust and to intake the air.

A central shaft **32** is not needed for the engine to operate. However a central shaft **32** can be driven through a set of coupling arms **33** as shown in FIG. **2**, attached to the blades **13** by means of the traction slots **15** and through a set of arm braces **34**, the ends of which are linked to the central shaft. Those link braces **34** are also useful to remove the RPM harmonic modulation on the shaft. Notice from FIGS. **1** and **2** that the central shaft assembly **32, 33, 34** is a sliding plug-in unit, easily removed through the back cover central hole **23** without dismantling the engine. In some applications, a central bearing attachment not shown is used to diminish the load pressure on the carriages **17** and against the opposite housing contour wall **12**. When a central bearing is used, carriage wheels **18** can be replaced by rubbing pads since their role is then only to maintain the carriages **17** properly aligned for adequate contour seal **24, 25, 26** angle. No tensioning device has been proven necessary to keep all carriages **17** in good contact with the housing contour wall **12**.

The assembly of carriage **17** and wheels **18** must be voluminous but not necessarily heavy, in order to fill a substantial volume in the chamber. Pivoting blades **13** are shaped with a filler tip **14** to allow the control of the residual volume in the upper and lower chambers at maximum pressure square configuration, as seen on FIGS. **1**. and **2**. left. The top of the filler tip **14** must be shorten such to permit an adequate compression ratio, and to insure that only a fraction of the gas is in the tiny interstices at the time of fire. Because the pressure pulse at top dead center is much shorter than in piston engine, the shape of the combustion chamber is much less critical. Carriage wheels **18** should be wide to reduce contact pressure with the contour wall **12**. To distribute wear, the front and back wheels **18** of the same carriage **17** are positioned off line with overlapping paths. For smoother operation, roller bearing are inserted in the blade's **13** hooks pivot **16**, to link friction free the cylindrical end of each pivoting blade **13** to the carriage **17** pivot surface.

A lateral seal for the low pressure applications is used on each side cover **21,22**, and is made of a compression ring along the pivot **16** path **20**. This quasi-elliptical seal is made of a slight deformation of a flexible metal sheet jacket (not shown). For high-pressure application, standard gate like linear seals **28** in the rotor blades **13** are provided. At pivots **16**, the lateral sealing is assumed by a set of arc blade pellets **29**, circular blade pellets **30**, and carriage grooved pellets **31**, all pressing against the side covers **21, 22**. The large blade pellet **30** gains to have a hole (not shown) in the center to prevent pressure push back.

Spring loaded housing contour seals **24, 25, 26** of different possible designs are incorporated in a groove in the carriages **17** between the axes **19** of the two wheels **18** to insulate the chambers. Each housing contour seal **24, 25 26** sits on a rocking carriage **17** in such a manner as to be always perpendicular to the engine housing contour wall **12**. For intermediary pressure applications, a sliding gate type seal **24** is used. A butterfly type seal **25** suitable for low to moderate pressure applications is made of a stack of flat springs, which has the advantage of a minimal course during the rotation, but may be subject to excessive friction at high pressure. An advanced split contour seal **26** design suitable for very demanding applications uses a sloped groove in the carriage **17**, and the internal chamber pressure to help maintaining itself in place at all time. This split contour seal design **26** uses the flat springs **27** anchored in the carriage **17** wheel area **18** also to oppose the tangential force. The split contour seal **26** contact point with the housing contour wall **12** is off the carriage **17** groove sloped plane for a positive pressure contribution.

For counter-clockwise rotation as a four strokes combustion engine, the four chambers are used in a sole circuit and the cycle is: intake, compression, expansion, exhaust. One of the left upper ports **37, 38** is fitted with a spark plug. The top right port **39** is closed with a removable plug **40**. Ports **41, 42** are intakes from a conventional carburetor or must be fitted with a gas or diesel injector. Exhaust is expelled at ports **43, 44**. In order to pass along the flame and make a continuous combustion engine, a small channel **36**, located along the internal housing contour wall **12** next to the spark plug **35** at port **37**, allows a voluntary flow back of hot gas into the next ready-to-fire combustion chamber when each of the contour seals **24, 25, 26** passes over **36**. The amount of flow can be controlled by screwing or unscrewing the spark plug **35**. This channel **36** is called the ignition transfer cavity or slot, and permits continuous combustion like in a turbine engine and in the same time generates a dynamically enhanced compression ratio in the almost ready-to-fire combustion chamber, allowing for a more complete and faster combustion. Furthermore, the four housing contour seals **24, 25, 26** are at variable distances during rotation, such as to permit an additional geometric volume pressure enhancement. The additional compression may lead to desirable or not photo detonation (kicking) and diesel pressure level when a diesel injector is located at spark plug **35** positions **37** and/or **38**. In the ports **38** of the side cover **21, 22**, the spark plug cavity is made large enough to withhold a small quantity of hot gas until the next ready to fire mixture comes up, which does allow for continuous combustion but without the dynamically enhanced compression ratio. Lateral ports **38, 42, 44** of the side cover **21, 22** offer better air-tight conditions while crossing in front of the ports due to the large carriage **17** lateral surface. An ignition timing advance can be built-in by slightly shifting the effective position of the spark plug **35** and/or the channel location **36**. By blowing high pressurized air into the spark plug holes **37, 38** or into the ignition transfer cavity **36**, the rotor accelerates until the self-starting point is reached. No synchronization of the sparks is required, and continuous high-frequency sparks or glow plug do. The exhaust in the side covers **21, 22** is progressive through a long arc port **44** which could allow, by flowing early exhaust through a standard Venturi, to produce a depression helping the late exhaust cleanup. This rotary engine **10** can also run as two parallel two strokes engine circuits, compression-expansion and compression-expansion, by blowing the exhaust with an intake mixture available from an external blower as in the conventional multi pistons two strokes engines.

As an additional feature, this rotary engine **10** requires few parts compared to a piston engine. Due to the continuous combustion and to its self-synchronized capability, this engine **10** is suitable for applications where high reliability is required. Average angular rotation speed of each pivot **16** (back and forth) of the pivoting blade **13** is about one third of the central shaft **32** RPM, while carriage wheels **18** rotate at 6 times the central shaft **32** RPM. This engine **10** central shaft **32** rotates at only a fraction of the maximum RPM of a piston engine except in detonation mode, with an idle under 200 RPM. Having a much better torque continuity than the piston engine, this engine **10** does require less flywheel effect and less gear box ratio for most applications.

To help cooling and reduce lubrication, at least one of the lateral side covers **21**, **22** has a large central hole **23** exposing the pivoting blades **13** central area of the rotor such that all parts of the engine **10** are external, except for the carriage **17** and wheels **18** which are always in good thermal contact with the housing contour **12**. A simple way to lubricate is to use a mixture of fuel and oil even in the four strokes engine mode, but more sophisticated applications could incorporate pressurized oil distribution systems. Since the seals are the only friction surfaces, the need of lubrication is minimized by an optimal choice of anti-friction materials.

Movement of the wheels **18** on the inner housing wall **12** allows for heat transfer and distribution to the whole housing **11**. The pivoting blades **13** are cooled by lateral contact, and by ventilating wings (not shown) located toward the central engine area. Since this engine **10** does not have any oil pan or inactive room, it is suitable for operation in all orientations, and in submerged or hostile environments. Furthermore, due to the continuous combustion, this engine **10** can be used under water as a self contained pump or jet propulsion unit, or in electrically conductive environments.

In addition to the internal combustion engine, this engine **10** can be used as a compressed fluid pneumatic, steam, or hydraulic energy converter motor. The engine **10** then uses the two quasi independent symmetrical chamber circuits in parallel, with all port plugs **40** removed. For counter-clockwise rotation, intakes are housing ports **37**, **41** and exits are ports **39**, **43**. Torque is generated symmetrically in the two opposed expansion chambers and adds up, and the rotor is almost self-starting. Except when ports are in the sides covers **21**, **22**, the direction of rotation can be reversed by reversing the direction of the flow. When used as a flow meter, the device **10** also works in both directions. Mechanically driven, this fluid energy converter motor **10** becomes a compressor, or a pressure or vacuum pump, with the same two quasi independent circuits working their own cycle. In compressor mode, this device **10** builds up pressure by adding four chamber volumes per revolution and per chamber circuit, without making use of a limiting check valve, providing that some temporary back flow is acceptable. Total pumped volume can reach up to 70% of the contour **12** volume per rotation. The housing **11**, the pivoting blades **13**, and the carriages **17** can be made of metal, glass, ceramic or plastic, the later mostly for compressor, pump or water hydraulic engine applications.

Calculation of the SAINT-HILAIRE's (from the name of the physicist who made the calculation) housing contour family of curves **12** is quite complex. To achieve the desired characteristics and to distribute stress and constraints on the housing **11**, a proper selection of distances between wheel axes **19** (Distw), wheel diameter **18** (Dw) and carriage **17** height (H) must be made. At first it is not obvious that such a contour exists, particularly a monotone one without lobes, but it does in practice within an interesting range of the deformation parameters (**P**) defined as the ratio of the minimum lozenge diagonal (LDmin) to the maximum (LDmax). As the rotor rotates, pivoting blades **13** align in a square configuration as in FIG. **1** and in the left arrangement of FIG. 2, with the upper and lower chamber at top dead center. At that moment, the two upper and lower carriages **17** tend to align themselves almost horizontally. The carriages **17** angle (Gsq) with the horizon in the square configuration, determines whether or not the rotor will need a central bearing support to stabilize lateral motion. To avoid the central support, we have selected for the housing contour **12** shown in FIGS. **1** and **2**, a deformation parameter (P) of 0.800, which leads to an angle Gsq of 28.00 degrees. For the current case (P=0.800), lozenge corner angle varies from 90.000+/−12.680 degrees.

A numerical spreadsheet application has been developed to calculate the contour family of curves. The method constrains the symmetry of the contour **12** only through the central housing axis and first calculates the profile (not a contour at this stage) of the centers of the carriage wheels **19**. Calculations start with an approximate profile of the wheel **19** centers and calculate the profile **20** of the carriage pivots **16**, which is imaged through the lozenge transformation into a quality control profile **20** of the pivots **16** about 90 degrees out of phase. Profile of the wheel centers **19** are then modified by Monte Carlo random perturbations method or convergent algorithm, until those two calculated profile **20** of the carriage pivots **16** and the profile **20** of quality control pivots **16** become identical and in coincidence. Close analytic mathematical match of the profile of the wheel centers **19** "cw" has been found to be of the following form, with three adjustable parameters (A, B, C):

$$Xcw=A\cdot(H+LD\mathrm{max}/2)\cdot(1-C\cdot ABS(\cos(Z)))\cdot\cos(Z);\ \text{Polar: Angle}=\arctan(Ycw/Xcw)$$

$$Ycw=B\cdot(H+LD\mathrm{min}/2)\cdot\sin(Z);\ \text{Radius}=\mathrm{Sqrt}(Xcw^2+Ycw^2)$$

Where Z is a generating angle, not the actual angle of the profile of the wheel centers **19** position. Error using this formula does not exceed 0.4%; a second order correction reduces this error by almost ten folds. Exact mathematical profiles do not exist except for some particular parameters selection. The length of the pivoting blade (Lz for lozenge side) is measured from the center of the cylindrical pivot **16** at one extremity to the center of the hook pivot **16** at the other. The following sets of parameter values, normalized to the pivoting blade **13** length (Lz), generate acceptable final profile of the wheel centers **19**. Corresponding parameters values are given below for 3 values of the deformation P:

Lozenge deformation parameter P=(LDmin/LDmax):

	0.800	0.750	0.700
Lozenge side (Lz) pivot to pivot	1.000	1.000	1.000
Distance between carriage wheel (Distw)	0.607	0.578	0.551
Carriage wheel diameter (Dw)	0.303	0.289	0.276
Height of the carriage (H)	0.152	0.144	0.138
Square carriage angle (Gsq)	28.00	22.62	16.72
Lozenge corners angle: 90 degrees +/−	12.68	16.26	20.01
Larger final profile diameter	2.258	2.245	2.231
Smaller final profile diameter	1.901	1.809	1.720
Constant A	1.048	1.036	1.022
Constant B	1.029	1.021	1.015
Constant C	0.422	0.586	0.778

For P<0.760, the profile **19** of the wheel centers and of the housing contour **12** start to show lobes. Those solutions are also mathematically acceptable, but do generate higher stress on the rotor. Housing contours **12** have also been calculated for two interesting limit cases:

a) instead of a carriage **17**, only one wheel, centered at the pivots **16** of the pivoting blades **13** (distance between wheel axes Distw=0, and carriage height H=0); and

b) no wheel at all, meaning that the pivot **16** of the pivoting blade **13** are rubbing on the housing contour wall **12** (additional constraint of wheel diameter Dw=0).

These configurations require in practice a central bearing support.

Final housing contour **12** is the profile of the wheel centers **19** enlarged by a wheel radius (Dw/2) all around, plus the thickness of any replaceable sleeve if used. The selection of an optimum contour is done for a high radius angular variation rate near top dead center, and such as the final expansion volume is near the volume generated by the movement of the variable tangential surface of push. Those wheel center **19** profiles and housing contours **12** generally look like a rounded corner parallelepiped with four zones of maximum curvature, or two lobes with six zones of maximum curvature at higher eccentricity, and contrary to vane devices these contours **12** allow for high-pressure ratio without any intake volume reduction.

We claim:

1. A rotary apparatus able to produce mechanical energy from pressurized fluids flow like hydraulic, steam, pneumatic, and internal combustion, or to pump, vacuum and compress, comprising:

A housing having an internal contour wall, including two planar side covers;

Four pivoting blades consecutively pivoted one to the other at their ends about parallel axes;

Four carriages external to, and pivoted on the ends of said pivoting blades, and carrying end parts in contact with said housing contour wall;

The assembly of said four pivoting blades and four carriages forming a four degrees of freedom X, Y, θ, Φ variable-shape rotor rolling inside said housing contour wall about a central axis;

Said rotor carrying filler tips;

A system of lateral seals in contact with the said side covers and a set of contour seals in contact with the said housing contour wall;

Four chambers of variable volume, each limited by two successive said contour seals, and extending in-between the said contour seals along the contour wall, and on the outward face of the said carriages, pivoting blade and filler tip;

A set of ports in the said housing and side covers for intakes and exhausts;

Wherein all consecutive compressions are occurring repetitively in the same housing areas, and all consecutive expansion are also occurring repetitively at a different intermediate housing areas;

Wherein the two compression housing areas are opposed, and alternate with the two as well opposed expansion housing areas;

Wherein successive compression strokes and expansion strokes start and end simultaneously;

Wherein the distance between two consecutive said contour seals increases and decreases during a revolution of the said rotor, such as to generate a geometric volume pressure enhancement.

2. A rotary apparatus as defined in claim **1**, wherein the said housing contour wall is generally shaped like a rounded corner parallelepiped, with four areas of maximum curvature and four intermediate areas of minimum curvature.

3. A rotary apparatus as defined in claim **1**, wherein to permit higher eccentricity to the said rotor, the calculated said contour wall is lobe shaped, with six areas of maximum curvature and six intermediate areas of minimum curvature.

4. A rotary apparatus as defined in claim **1**, wherein the contour of the said contour wall is one of a family of curves, and the method for calculating those contours includes the following calculation steps:

Symmetry is constraint only about the central axis of the housing, which allows also acceptable mathematical solutions not symmetrical through the x- or y-axis;

Starting from an approximated empirical profile of the wheel centers on which the movement of a carriage generates a profile of the carriage pivots (which is not an housing contour yet at this stage);

Imaging this profile of the carriage pivots through the lozenge transformation generates a quality control profile of pivots about 90 degrees out of phase;

Adjusting the empirical profile of the wheel centers until the profile of the carriage pivots and the quality control profile of pivots become identical and in coincidence, by using a set of Monte Carlo random perturbations or convergent algorithm;

Final said housing contour is obtained by enlarging the said profile of wheel centers by one wheel radius all around;

For large eccentricity, some calculated profile of pivots and said contours show lobes, but are still acceptable;

For the limit case wherein the distance between the two said wheels of the same said carriage are set to zero and said wheel positioned at the said pivot, acceptable profiles are still obtained, even for a said wheel diameter equal to zero,

Selection of an optimum said contour is done for high angular radius variation rate near top dead center, and such as the final said chamber expansion volume is near the volume generated by the movement of the tangential surface of push.

5. A rotary apparatus as defined in claim **1**, wherein each pivoting blades comprises:

One hook at one end, and a cylinder at the other end, so that four pivoting blades can be firmly assembled together to allow with the carriages, a four degrees of freedom movement;

A roller bearing inserted in each said hook, linking friction free the cylindrical end of the pivoting blade to the carriage pivot surface; and

Each said pivoting blade having a traction slot toward the central rotor area allowing to drive a central shaft attachment mechanism.

6. A rotary apparatus as defined in claim **1**, further comprising:

A wheel in contact with the said contour wall at each end of the said carriage;

A central receptacle in the said carriage in-between the two said wheels, and in rocking contact with the outside of the said pivot; and

An axial groove in said carriage to carry one of said contour seal, located on each said carriage at an equal distance of the said two wheels.

7. A rotary apparatus as defined in claim **1**, wherein said filler tip is fixed to and extend outwardly forms the said pivoting blade between two consecutive carriages.

8. A rotary apparatus as defined in claim **1**, wherein said filler tips are fixed to and extend outwardly forms the said two carriage ends pertaining to the pressure chamber.

9. A rotary apparatus as defined in claim **1**, wherein said ports are radial housing ports for a spark plug, intake and exhaust, located near where the contour seals stand at top dead center.

10. A rotary apparatus as defined in claim **1**, wherein said ports are lateral side cover ports for a spark plug, intake and exhaust, located on the pivoting blade pivots path, and near the blade pivot positions when at top dead center.

11. A rotary apparatus as defined in claim **1**, comprising a set of said housing contour seal made as a spring loaded sliding gate type.

12. A rotary apparatus as defined in claim **1**, comprising a set of said housing contour seal using a stack of flat springs held midway by a semi circular insert and called butterfly type, suitable for moderate pressure applications.

13. A rotary apparatus as defined in claim **1**, comprising a set of said advanced split contour seal, using a carriage sloped groove and the internal chamber pressure to help maintaining the said seal in place at all time, and suitable for very demanding applications.

14. A rotary apparatus as defined in claim **1**, having a system of said lateral seal carried by the said blades and carriages, comprising:

A linear seal on each side of the said pivoting blade;

An arc pellet seal on each side of the said hook end of each said pivoting blade;

A circular pellet seal on each side of the said cylindrical end of each said pivoting blade; and

A carriage grooved pellet seal on each side of the said carriage around the said contour seal.

15. A rotary apparatus as defined in claim **1**, wherein the said lateral seals include:

An arc pellet seal on each side of the said hook end of each said pivoting blade;

A carriage grooved pellet seal on each side of the said carriage around the said contour seal; and

An almost elliptic static pressure ring on each of the side cover pivots path, which by design is in permanent contact with the rotor, for moderate pressure applications.

16. A rotary apparatus as defined in claim **1**, comprising:

Several removable intake and exhaust plugs, which are used to convert the 2 parallel compression and expansion circuits into a sole serial circuit;

Two quasi independent circuits used in parallel with the plugs removed for operation as a two stroke rotary internal combustion engine, a fluid energy converter, a compressor, a vacuum pump and a flow meter; and

Two quasi independent circuits used in serial by plugging intermediate ports, to make a four strokes internal combustion rotary engine.

17. A rotary apparatus as defined in claim **1**, wherein:

The said carriage wheels are of cylindrical shape, and in direct mechanical contact with the said housing contour wall, thereby increasing the combustion chamber walls thermalization, heat transportation and dissipation; and

At least one of the two side covers has a large central hole exposing the blades central area of the rotor, thus limiting the number of the internal parts to the carriages and their wheels, and so improving the cooling and reducing the need for lubrication.

18. A rotary apparatus as defined in claim **1**, comprising:

A central shaft coaxial with the central housing axis, crossing the two side covers and supported by bearings in at least one of the side covers;

A central shaft coupling mechanism composed of at least two crossing arms attached to the said pivoting blades traction slots and to a set of moving arm braces, wherein the ends of said arm braces are linked to the central shaft;

Wherein the shaft coupling mechanism is made as a sliding plug-in unit, easily removed without dismantling the apparatus;

Wherein the shaft coupling mechanism contributes to remove the RPM harmonic modulation on the shaft; and

Wherein the shaft gives full power takeoff at both of its ends.

19. A rotary apparatus as defined in claim **1**, when used as internal combustion engine, having:

An ignition transfer slot cut into the housing contour wall, located where the forward carriage contour seal stand at maximum chamber pressure, such as to allow a flame transfer from one chamber to the next, and permitting continuous combustion;

The said ignition transfer slot allowing the injection of high pressure hot burning gas into the next ready to fire chamber, to produce a dynamically enhanced compression ratio.

20. A rotary apparatus as defined in claim **1**, wherein when used as internal combustion engine, at least one side cover has a spark plug cavity made large enough to retain a small quantity of hot gas sufficient to alight the following ready to fire combustion chamber, whereas to make the engine in continuous combustion mode.

21. A rotary apparatus as defined in claim **1**, wherein in engine mode:

The two facing intake said ports located one on each side of the engine are easily accessible to permit independent and stratified admission of fuel and air;

Said pivoting blades and carriages are made very strong; and

The intake chamber area is kept cold, such as to permit engine photo-detonation mode and direct hydrogen combustion.

* * * * *

A 37-page patent
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US005674059A

United States Patent [19]

Bucur

[11] **Patent Number: 5,674,059**

[45] **Date of Patent: Oct. 7, 1997**

[54] **RECIPROCATING VARIABLE DISPLACEMENT ROTARY VANE MACHINE**

[76] Inventor: **Alexandru A. Bucur**, 2270 Mitchell Rd., Norcross, Ga. 30071

[21] Appl. No.: **544,536**

[22] Filed: **Oct. 18, 1995**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 185,656, Jan. 24, 1994, abandoned.

[51] **Int. Cl.**^{6} **F01C 21/16**

[52] **U.S. Cl.** **418/28**; 418/1; 418/26

[58] **Field of Search** 418/1, 24, 26, 418/28

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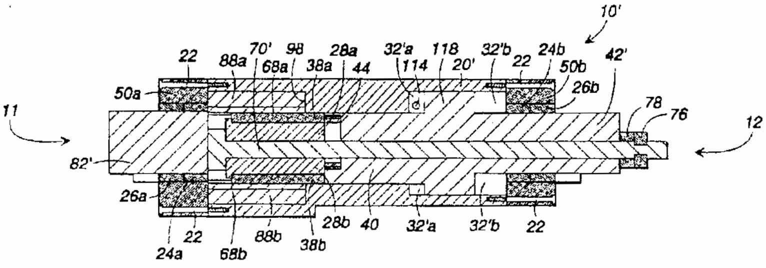
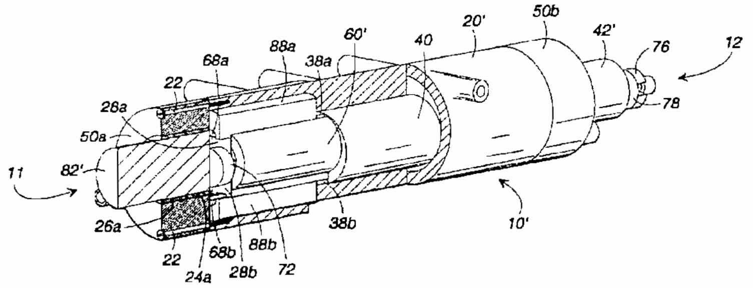
[57] **ABSTRACT**

An first rotor and an second rotor rotate about a longitudinal axis in a housing. The second rotor moves longitudinally relative to the first rotor. Rotor vanes extend outward from the rotors and are longitudinally split into longitudinally extending second vanes and longitudinally extending first vanes that slide longitudinally relative to one another. The second vanes travel longitudinally with the second rotor relative to the first rotor, and the second vanes slide relative to the first vanes that remain with the first rotor. The second rotor and the second vanes move longitudinally toward and away from a recess defined by the first rotor such that the active surface area of the rotor vanes is varied. When the second vanes slide away from the first vanes, surfaces of the first vanes are exposed that reciprocate into and out of specially defined chambers in a pump-like fashion. A movable element is connected to and extends from the second rotor. The movable element interposed between the variable displacement chamber that the second rotor operates in and another chamber such that when a change in the differential pressure between those chambers occurs, the movable element moves the second rotor such that the displacements of the variable displacement chambers is varied in an automatic feedback fashion.

7 Claims, 18 Drawing Sheets





Letter from Cairo Greg Spice

Charity of fallen angels

DURING the holy month of Ramadan Muslims make a serious effort to deny themselves sensual pleasures in order to get closer to God. From sunrise to sunset, for the duration of the month, smoking, drinking of liquids of any kind, eating and engaging in sexual contact are all prohibited. In public at least, most of the country makes an earnest display of self-denial and brotherly/sisterly love.

The vast majority of Egyptians are good-natured and emphatically non-violent. During the holy month everyone seems to make an even greater effort to be particularly considerate and caring. This, in spite of the shredded nerves of a whole country undergoing mass nicotine and caffeine withdrawal and the composure-shattering chaos of Cairo's horn-blaring, gridlocked traffic.

One of the enduring traditions of the holy month is that wealthy citizens pay for tables to be set out in the streets, to which the poor are invited to share a lavish meal as the whole country breaks its day-long fast. By feeding the poor, the wealthy are punting on greater rewards when they get to heaven. It is a tradition dating back a thousand years to the time of the Fatimids, when the Caliphs used to provide the needy with food in their palaces.

Over the past few weeks bemused Cairenes have been treated to the spectacle of affluent businessmen, film stars and entertainers trying to outdo one another to see who can provide the most generous spread. One of them, at whose table a place is much sought-after by the city's hungry legions, is the famous belly dancer, Fifi Abdoo.

Ms Abdoo is very wealthy, having practised her art for many years. This has mostly involved dancing for specially organised parties, at which men from all over the Middle East vie with one another in shower-

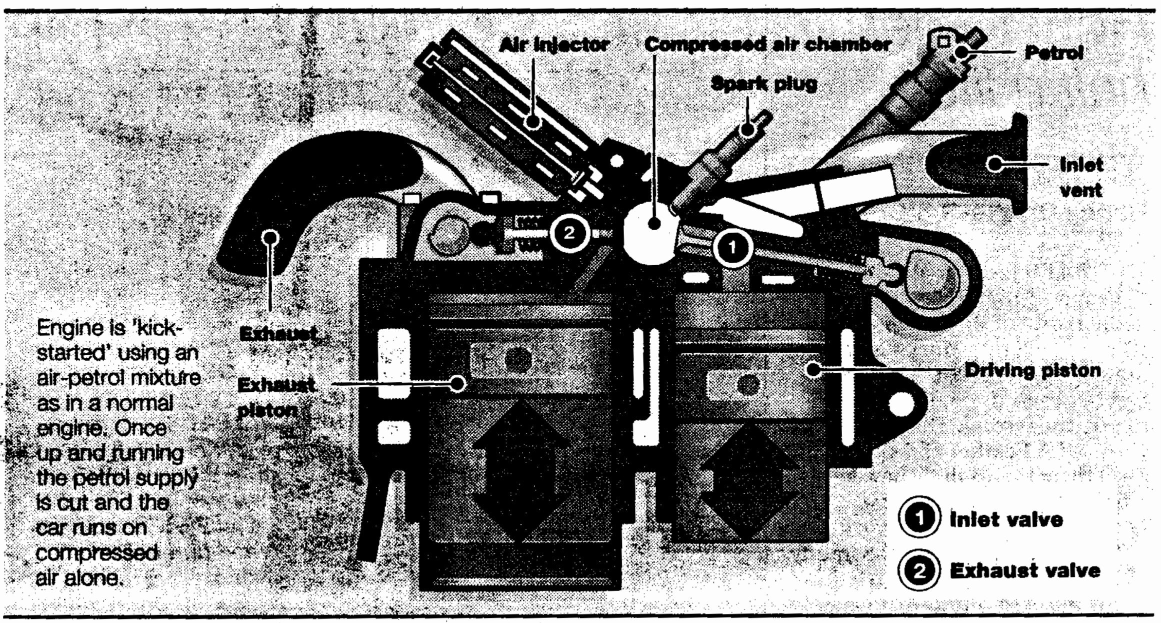
dancer's money is sinful; that people who eat at her table are sharing in this sin because it is encouraging Ms Abdoo to continue practising her particular brand of dirty dancing.

The controversy has dominated newspaper gossip columns and conversation in salons and souks up and down the Nile. The reason for the intense interest lies in the ambivalent role played by belly dancers in Egyptian society. While there seems to be a sort of reverence for them, they are at the same time considered shameful — a bit like much-loved fallen angels.

Until about 10 years ago most women in Egypt's cities and towns had adopted Western dress habits. Now the trend is being reversed. Most women do not go out in public unless at least their heads are covered with a scarf, and increasingly unless their faces are fully covered. So while the culture clothes its wives and daughters in the fabric of sainted maidens, there is great demand for women willing to shed the fabric, bare their bellies and titillate the men with the art of their dance.

Most of the dancers come from the city's slums. When some attain fame and fortune, their rags-to-riches stories are heavily romanticised by the Egyptian media. But since the culture judges them essentially immoral, they are always portrayed as tragic figures. The compromise is to sentimentalise them; typically as whores with hearts of gold.

THE conservatives who decry Ms Abdoo's charity as tainted lack popular support. Most people seem to agree with Egypt's Grand Imam, Sheikh Tantawi, the country's principal authority on religious matters. He publicly countered the conservatives' claims by emphasising the importance in Islam of the idea that whoever helps the poor will be rewarded by God. It was not for others, he said, to judge



Engine is 'kick-started' using an air-petrol mixture as in a normal engine. Once up and running the petrol supply is cut and the car runs on compressed air alone.

A car with a healthy air

Paul Webster in Paris

A FRENCH engineer has invented an urban car that runs only on the air around us. The first ZP taxi — ZP stands for zero pollution — will be unveiled in Provence later this month before going into mass production in Mexico.

The inventor, Guy Nègre, opened his engine laboratory at Brignoles in the Var three years ago to perfect a motor that runs on a tankful of compressed air. In urban road trials, his air-driven engine mounted in a Citroen AX chassis ran for 10 hours with a top speed of about 100kmh. That is a better performance than any electric car in production.

The Mexican version of the vehicle was designed by an Italian company and resembles a small family saloon with a separate compartment for the driver and four seats at the back.

A Mexican government licensee, Dina, has signed a contract to produce an estimated 40,000 ZP taxis and urban delivery vehicles a year. It hopes to replace all of Mexico City's 87,000 petrol and diesel taxis.

Mr Nègre, who worked on high-performance and Formula One engines for 30 years, runs his business, CQFD Air Solution, with his son, who is a former Bugatti engineer, and 16 employees just off the Mediterranean motorway to Nice.

His silent, odour-free engine design was chosen for the world's most polluted city after a worldwide search by the Mexican authorities that included tests on dozens of electric and other non-polluting experimental vehicles.

"My car was the only one totally dependent on compressed air for city running," says Mr Nègre. "Compressed air is used to start Formula One cars but in this case the compressed air is the fuel driving a motor with classic components such as pistons and valves. But it is much lighter than the average engine."

Sixteen patents have been taken out to cover an integrated system in which 300 litres of compressed air can be pumped into the tank under high pressure in three minutes. The car can also be refuelled at home in four hours by a small compressor in the car linked to the house electricity supply. While the air is free, the electricity used to refuel the tank at home would cost less than $2.

The car is being studied by other countries, including the Netherlands, because it can also clean up air that has been polluted by petrol vehicles.

"One of the vehicle's advantages is the carbon filtering system, which means that the car sucks in the polluted surrounding air during braking and then breathes out purified air," says Mr Nègre.

Notes & Queries Joseph Harker

Negre Compressed Air Engine

039

A slice of bad luck

of nvCJD.

This is a startling result. But what makes it more significant is that Dr Collinge extended the technique to look at other species. He found that in mice and macaque monkeys that had been deliberately infected with BSE, and in cats and kudu (a type of antelope) that had been accidentally infected with it, the western blots of their prions were almost identical with the pattern found in nvCJD in people. The same pattern was also, it almost goes without saying, found in BSE-infected cattle.

The reason for the different patterns is not totally clear. But what is probably happening is that each type of prion disease in a particular species is caused by a differently twisted prion. Since the twisting has such profound biochemical effects in other areas, it probably also affects the ease with which a protein can be glycosylated or, alternatively, the ease with which healthy proteins of different levels of glycosylation can be subverted.

This leaves biologists with a lot of explaining to do. The prion theory of diseases such as CJD was resisted for a long time, because it was difficult to see how a malformed protein could act as a template to twist healthy proteins into exactly the same shape. But there are tens of thousands of different proteins in the body and only one is known to behave in this way. So it could just be a fluke. However, if there are several ways to twist a prion-protein into a prion, and if each is faithfully replicated not only within an animal, but between animals and even between species, that demands a more systematic explanation.

The study also raises other questions, some academic and some practical. It may, for instance, help to shed light on the vexed problem of where BSE came from in the first place. The common belief is that it was the result of cattle eating proprietary feeds that included sheep offal, and that the reason Britain was so acutely afflicted was that the rules for treating such offal were changed in 1979 in ways that permitted the prions to survive. This suggests that BSE is derived from scrapie, a common prion disease that affects sheep.

But scrapie does not resemble BSE in detail. Part of the problem in proving any link is that there are many strains of scrapie. Dr Collinge's work will certainly allow these strains to be characterised better. If enough samples of brains from sheep affected with scrapie before BSE emerged can be found, his methods may be able to show if one of the strains was a likely precursor to the cattle disease.

Such a finding would be interesting, but it would not be of much immediate, human consequence. A more practical spin-off from the work may be a test for nvCJD that does not involve extracting a sample from a living patient's brain. And the better understanding that the study and its follow-ups should bring of just how prion diseases work should eventually help in attempts to find a cure.

For people worried about the progress of any human nvCJD epidemic there is a more immediate piece of good news. In December 1995, Dr Collinge reported on a group of mice he was experimenting with. Some of them had had their prion-protein genes knocked out and the equivalent human gene inserted instead. Such mice, when injected with material from the brains of people who had died from CJD (in this case, one of the old varieties; nvCJD had not been discovered when the experiment started), died quickly, usually within 200 days of the injection. Those that had been injected with BSE-infected material had fared better. They remained alive after some 270 days. Now, after almost 600 days, most of them are still alive, and those that have succumbed have not died of BSE.

This suggests that, while the BSE prion can subvert the normal human protein, that protein is not a pushover. So the scientific message for the moment seems to be that nvCJD is a real disease, different from other forms of CJD. It is, as far as it is possible to tell, BSE in another guise. But, with luck, it is difficult to catch.

Car engines

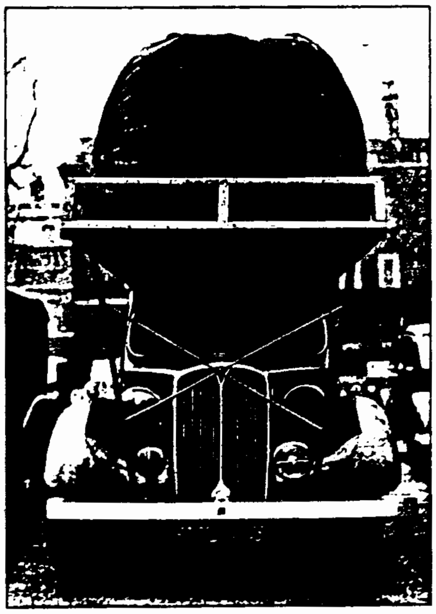
Not all hot air

THERE is something silly about the four-stroke petrol engine. Although it is the workhorse of almost all passenger vehicles, it suffers from some glaring inefficiencies. Only one of the four strokes of the piston provides power to the car, while during part of another stroke the piston is moving against the pressure of the ignited fuel. All of this is an extravagant waste of energy.

Such compromises are necessary because of an oddity in the engine's design—namely that the initial compression of the combustible gas, its ignition by the spark plug, and the power-producing expansion that follows, all occur in one and the same place, at the top of the same cylinder. Over the years, alternative designs have been proposed that ease this constraint. Guy Nègre, an engineer in Brignoles in France, whose background is in Formula One engine design, thinks he has hit on a particularly ingenious variant, which can run far more efficiently and cleanly than a four-stroke engine on the same amount of petrol. As a bonus, and without any modification, the engine can also be made to run on nothing more than compressed air.

At the heart of Mr Nègre's engine is a small combustion chamber. A piston in a compression cylinder outside this chamber forces air through a valve into it, compressing and thus heating a mixture of air and petrol in the process. With all valves to the chamber closed, the hot mixture is ignited. The design of the engine allows the fuel to burn over a period up to four times longer than in a four-stroke engine. The longer burn time means that the fuel is consumed far more completely, leading to less in the way of unwanted by-products, such as carbon monoxide and nitrogen oxides.

In the final part of the cycle, the hot gas escapes through a valve into a separate expansion cylinder, where it drives a piston, cooling in the process. One of the benefits of having separate compression and expansion cylinders is that the expansion cylinder can be made several times larger than the compression cylinder. This takes maximum advantage of the stroke that provides the engine's power. Another benefit is that, at the end of this expansion, the gas is at atmospheric pressure and a temperature of only 100°C. The output of conventional engines, by contrast, is usually at a pressure of several atmospheres and a temperature of 500°C, which means that lots of potentially



The reserve fuel tank

useful energy is being thrown away, and demands a complicated exhaust system to cool and depressurise the gases. As a result of these advantages, Mr Nègre's engine is some 50% more efficient than the four-stroke variety.

The benefits of the design do not stop there. Because the expansion piston provides power at every second stroke, rather than every fourth, Mr Nègre's engine provides the increased mechanical efficiency of the two-stroke engines common on motorcycles. Yet unlike such engines, it pollutes much less and is a great deal quieter, because the explosion of the fuel happens in the small combustion chamber rather than being allowed to propagate through the cylinder, as in conventional motors. The design also allows the engine to be light: fully functioning test versions weigh only 34kg (75lb).

But the most surprising aspect of Mr Nègre's invention is that it does not necessarily need petrol at all. He has found that forcing a burst of cold compressed air into the combustion chamber can deliver sufficient power to the piston to drive a car. While engines running on compressed air are nothing new, the novelty in this case is that cold compressed air at 40 atmospheres of pressure is being added to that chamber when it has already been charged up with air by the compression stroke. Since compressing air also heats it[redacted] A hot gas expanding can provide a lot more useful mechanical energy than the same quantity of cold gas at the same pressure. Although less powerful than a petrol model, the zero-emission version of Mr Nègre's engin[redacted]

This clean engine does, however, require a source of compressed air. One way to do this would be to have an electrically driven compressor on board. In other words, to make the car an electric one in disguise. But rather than having to wait ages for batteries to recharge, a pressure refill at the local petrol station would take only a minute. And with the savings made by having a smaller, lighter engine and no exhaust, a car could easily accommodate a compressor that could run off the energy produced by braking. In contrast to an ordinary electrically powered car, though, this one could easily be switched, while driving, from compressed-air injection to fuel injection, giving it the necessary power to zip along a motorway.

The first commercial prototype of Mr Nègre's engine, unmemorably named the MDI-EV3, is currently being tested [redacted] a small engineering outfit that he has set up, for use in cars and buses. With the backing o[redacted]n engine developer in Luxembourg, ADMP hopes to sell a licence for its technology to a big engine-manufacturer. Public transport should provide a convenient test-market for the engine, and MDI has already begun discussions with the[redacted], as well as with private bus firms, to equip urban buses with the compressed-air engine. A Parisian bus could run an entire day on 1,500 litres of compressed air, which could be stored on board. If Mr Nègre's brainchild takes off, Parisian smog may one day be reduced to the fumes of Gauloises.

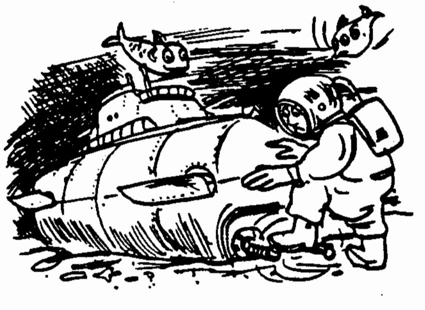
How to avoid jump-starting your submarine

IT IS a cold winter's morning, you are late for work, and the last thing you need is a flat battery in your car. But it could be worse: you might be a submarine captain. Say there was a war, and your sub's battery was dead?

The Australian navy does not want to have to jump-start its new generation of Collins-class submarines. Nor does it want to see their capacity for battery-powered underwater operations limited by uncertainty about how much energy is left in their batteries. Although the submarines' main motive power is provided (like that of most non-nuclear submarines) by diesel engines, when the boats are running too deep to draw air from the surface via a snorkel they must rely exclusively on their batteries. All of which has inspired John Charlesworth, at the Aeronautical and Maritime Research Laboratories in Melbourne, to come up with a new "fuel gauge" for lead-acid batteries.

The batteries of a Collins-class submarine are like the ones found in cars, only larger. There are 400 of them in each boat, and they weigh one tonne apiece and cost a total of A$10m ($8m) per vessel. They are a big version of an old idea: lead-acid batteries for underwater propulsion were first tested late last century.

But although the lead-acid battery is more than a century old, nobody has yet been able to devise a reliable fuel gauge for it. Most attempts have focused on measuring the amount of current flowing out of a battery during use, and into it during charging. But this technique is only partially successful, since not all the charging current winds up actually charging the battery. Some of it is lost as heat, and the losses vary with a battery's age and use. Moreover, the rate at which charge is sucked out of a battery influences the total amount of energy that can be drawn from it. The slower the trickle, the more efficiently it can be discharged.



Dr Charlesworth has come up with a new approach. As a lead-acid battery discharges, it creates lead sulphate out of the lead at the anode and lead dioxide at the cathode. These reactions use up the sulphuric acid in the battery fluid, and create water instead. That, in turn, dilutes the acid in which the electrodes are bathed. When the battery is charged up, the reverse happens and the acid concentration rises. Instead of measuring the current in and out, Dr Charlesworth uses a set of sensors that are immersed directly in the battery. Just as important, he has devised a computer model for interpreting what the sensors are telling him.

The sensors track the chemical reaction inside the battery by providing a continuous measurement of temperature and acid concentration, and the rate at which that concentration changes as the battery discharges. The all-important sensor that follows the sulphuric-acid concentration is based on a quartz-crystal oscillator, whose vibration characteristics depend on the acid's strength.

This, together with temperature data from a commercially available thermistor (a type of electronic thermometer), is interpreted by a microprocessor that contains Dr Charlesworth's software model of battery behaviour. The model, which is based on data from the actual performance of batteries, as well as the theory of how they ought to perform, is able to calculate the level of charge, and how long the battery it is monitoring can last at any given discharge rate. According to Dr Charlesworth, the system has performed well in tests involving charging and discharging a single large battery over several months. He expects that the new battery fuel gauge will come in handy in battery-powered vehicles that run on dry land as well as those running down under in both sense of the phrase.

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Refine Search IN/Negre AND IN/Guy

	PAT. NO.		Title
1	6,397,579	**T**	Internal combustion engine with constant-volume independent combustion chamber
2	6,363,723	**T**	Method and device for reacclerating a vehicle equipped with high-pressure air compressors
3	6,334,435	**T**	Method for operating pollution-free engine expansion chamber and expansion chamber therefor
4	6,327,858	**T**	Auxiliary power unit using compressed air
5	6,311,486	**T**	Method for operating a pollution-reducing engine
6	6,305,171	**T**	Method and device for additional thermal heating for motor vehicle equipped with pollution-free engine with additional compressed air injection
7	6,094,915	**T**	Method and devices for eliminating the pollution of cyclic internal combustion engines with an independent combustion chamber
8	5,592,904	**T**	Method and devices for controlling the combustion of a four stroke engine
9	4,810,201	**T**	Electrical coupling using a material having shape memory
10	4,788,945	**T**	Process and apparatus for controlling a gas evacuation circuit of a rotational distribution motor
11	4,781,605	**T**	Shape memory element for connecting braid onto a connector
12	4,574,749	**T**	Counterbalanced piston rotary machine
13	4,506,636	**T**	Device for controlling a gas circuit of a combustion chamber and a sealing member for its operation

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US005592904A

United States Patent [19]

Negre

[11] **Patent Number: 5,592,904**

[45] **Date of Patent: Jan. 14, 1997**

[54] **METHOD AND DEVICES FOR CONTROLLING THE COMBUSTION OF A FOUR STROKE ENGINE**

[76] Inventor: **Guy Negre**, Forum Aurelia, Route du val, Brignoles, France, 83170

[21] Appl. No.: **360,678**

[22] PCT Filed: **May 2, 1994**

[86] PCT No.: **PCT/FR94/00503**

§ 371 Date: **Jan. 26, 1995**

§ 102(e) Date: **Jan. 26, 1995**

[87] PCT Pub. No.: **WO94/25743**

PCT Pub. Date: **Nov. 10, 1994**

[30] **Foreign Application Priority Data**

May 3, 1993 [FR] France 93 05542

[51] **Int. Cl.**^{6} **F02B 19/06**; F01L 7/02

[52] **U.S. Cl.** **123/52.3**

[58] **Field of Search** .... 123/182.1, 52.2, 123/52.3, 52.4, 258, 292, 143 A

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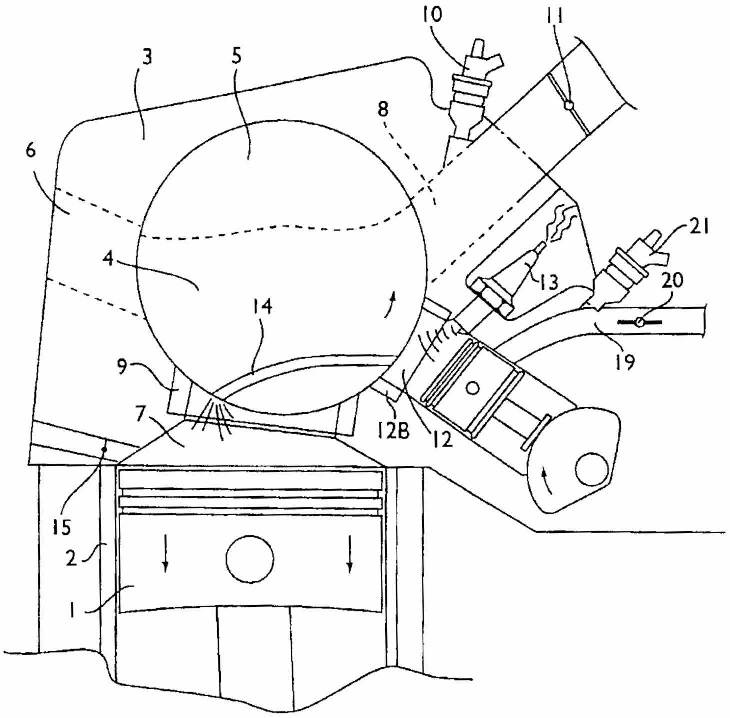
Primary Examiner—Marguerite McMahon
Attorney, Agent, or Firm—Greenblum & Bernstein P.L.C.

[57] **ABSTRACT**

Method and devices for controlling the combustion of a four-stroke engine. For each cylinder, in addition to the main combustion chamber, a smaller secondary combustion chamber is provided. The secondary combustion chamber is completely separate and independently supplied with a compressed fuel-air mixture such that, when the mixture is ignited, the explosion that takes place through a transfer channel into the main combustion chamber, igniting the mixture contained therein. The main combustion chamber is not supplied with fuel at low speeds. Application is also contemplated for four-stroke engines with spark or other ignition and with rotary or valve timing.

28 Claims, 7 Drawing Sheets



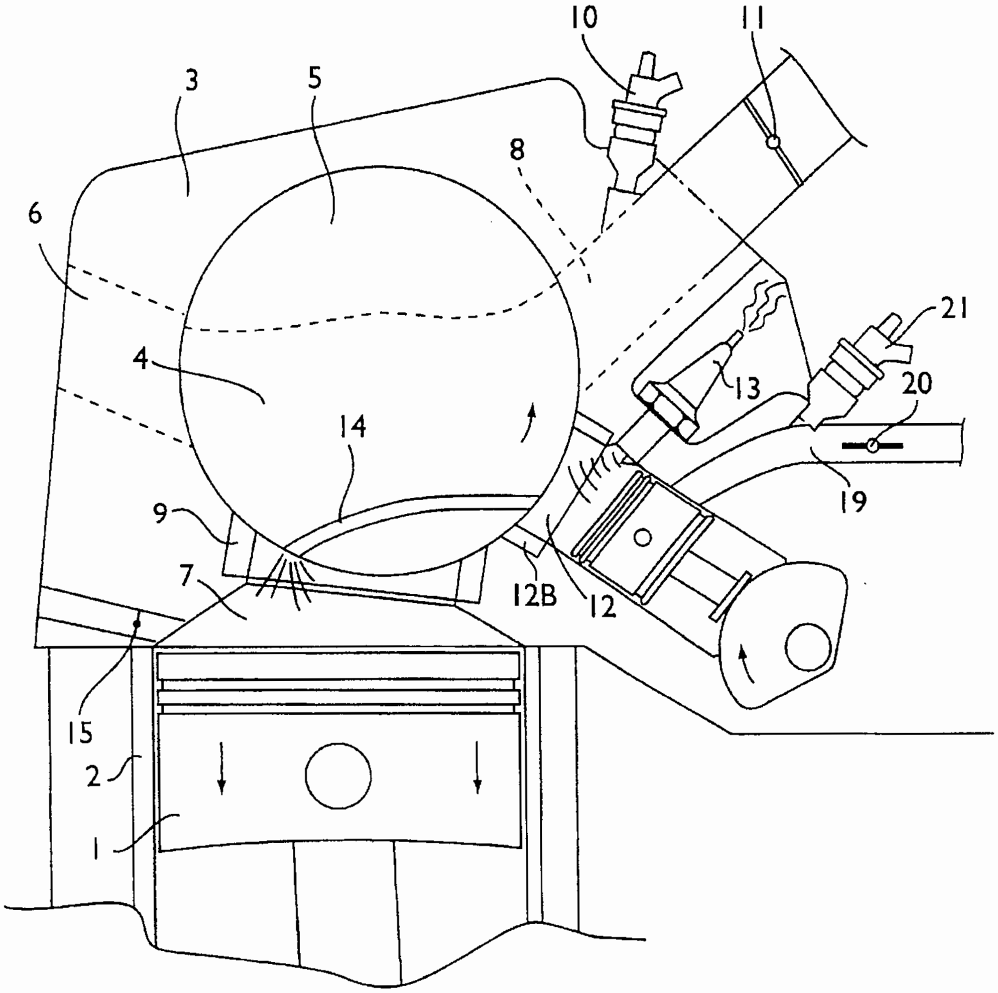


FIG. 1

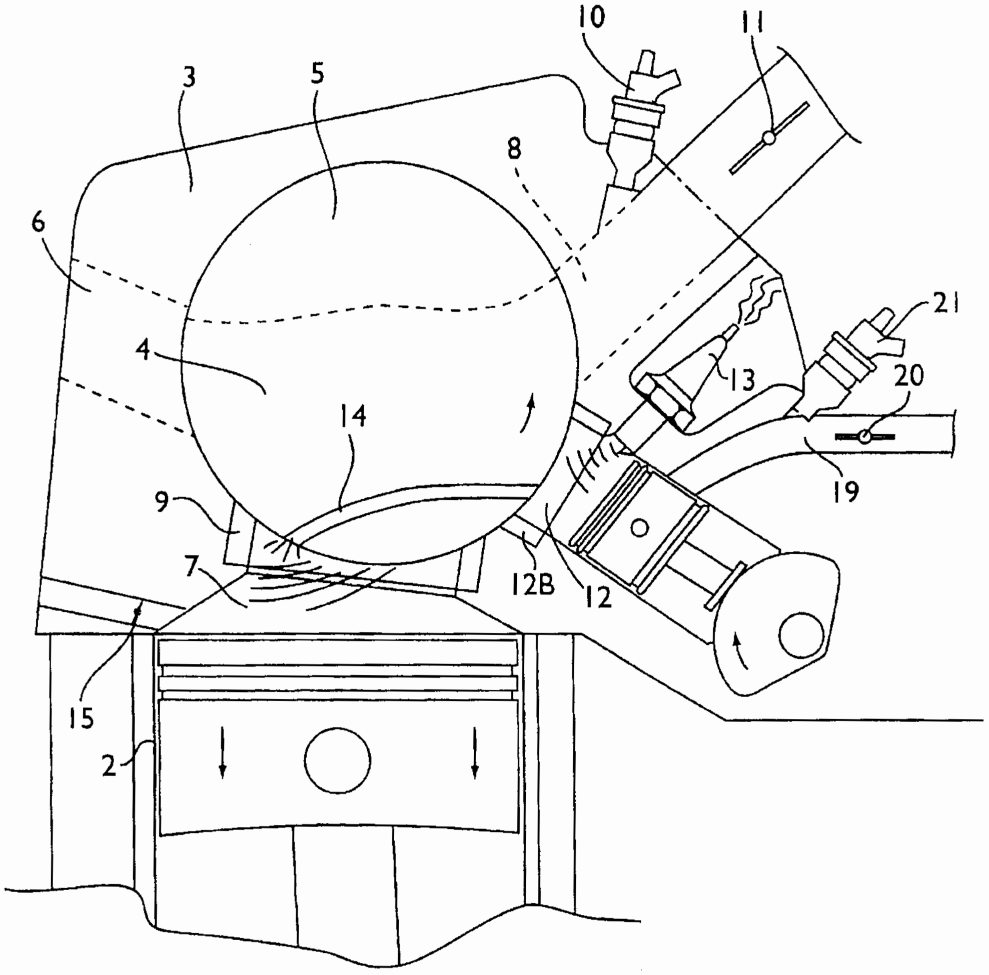


FIG. 2

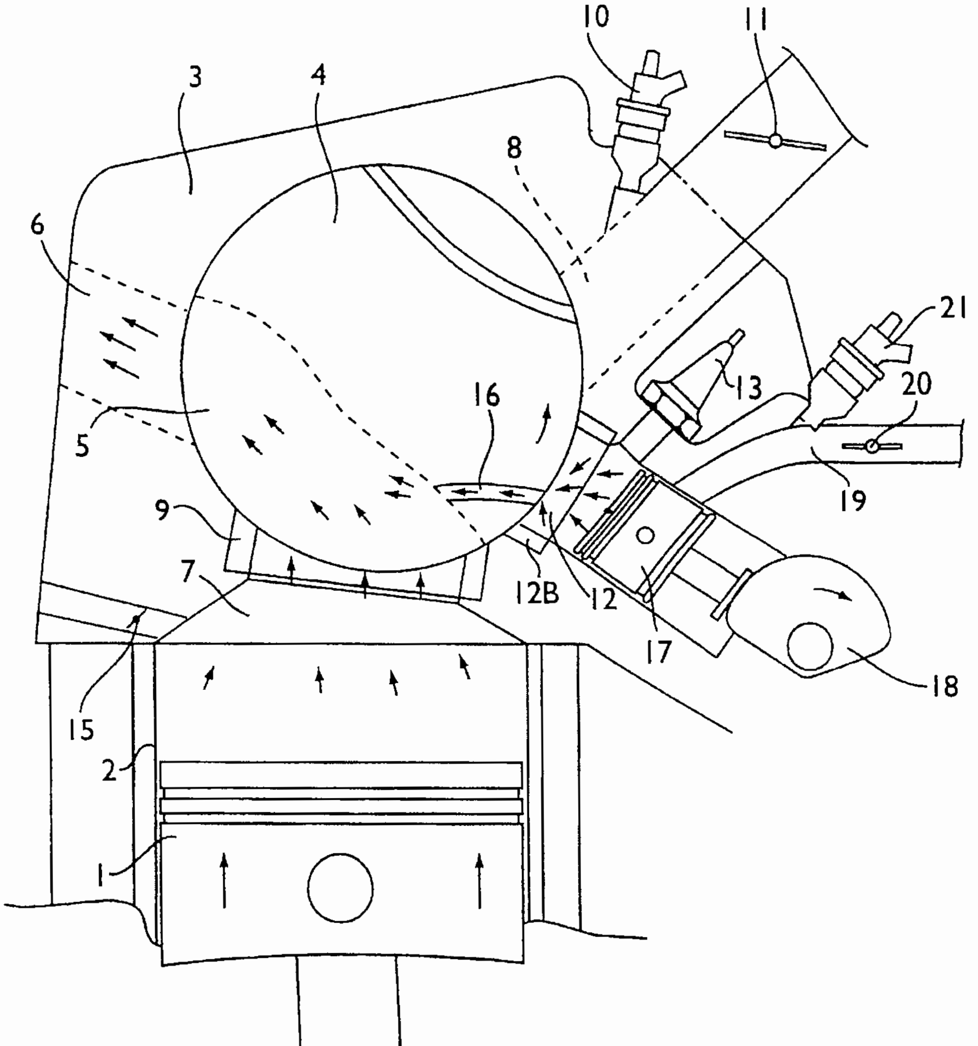


FIG. 3

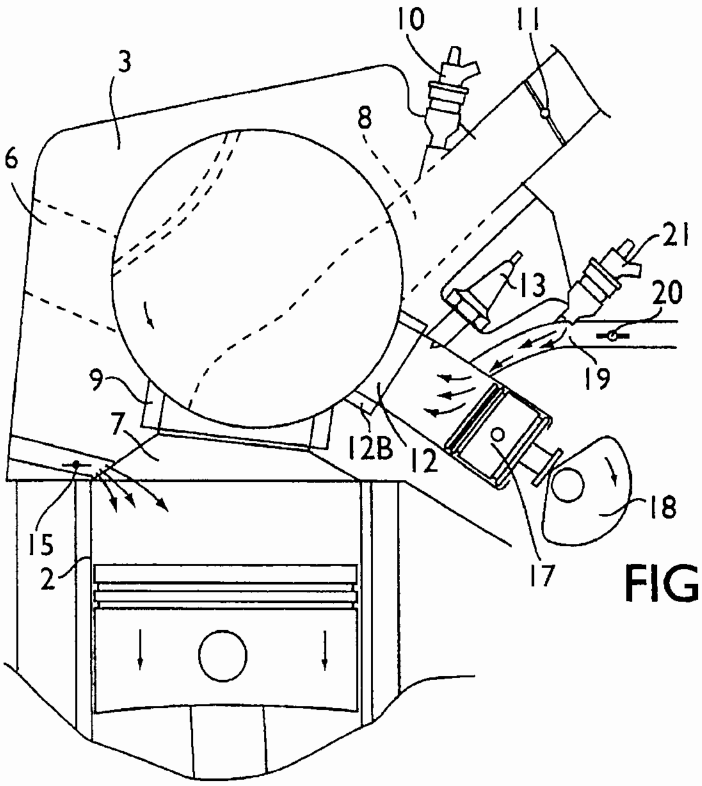


FIG. 4

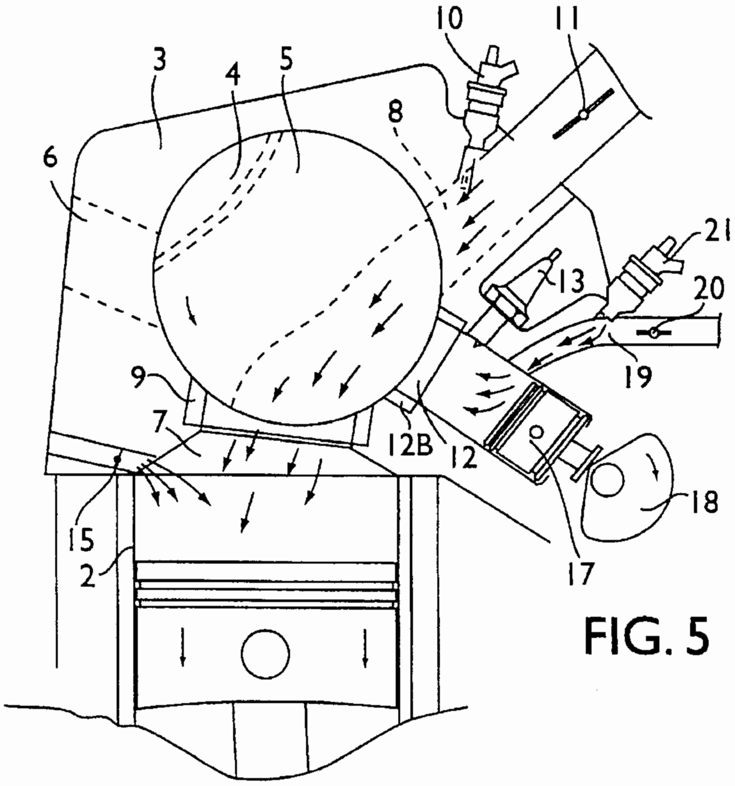


FIG. 5

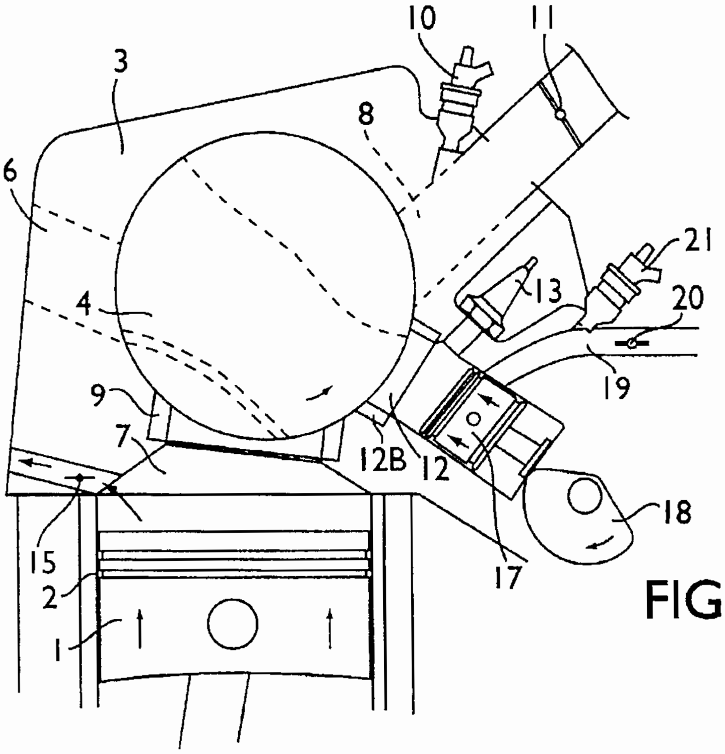


FIG. 6

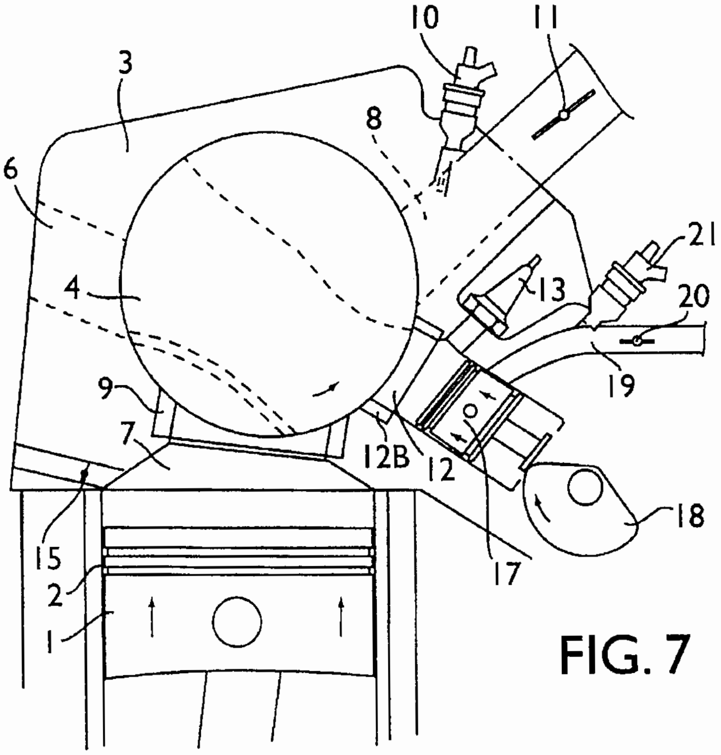


FIG. 7

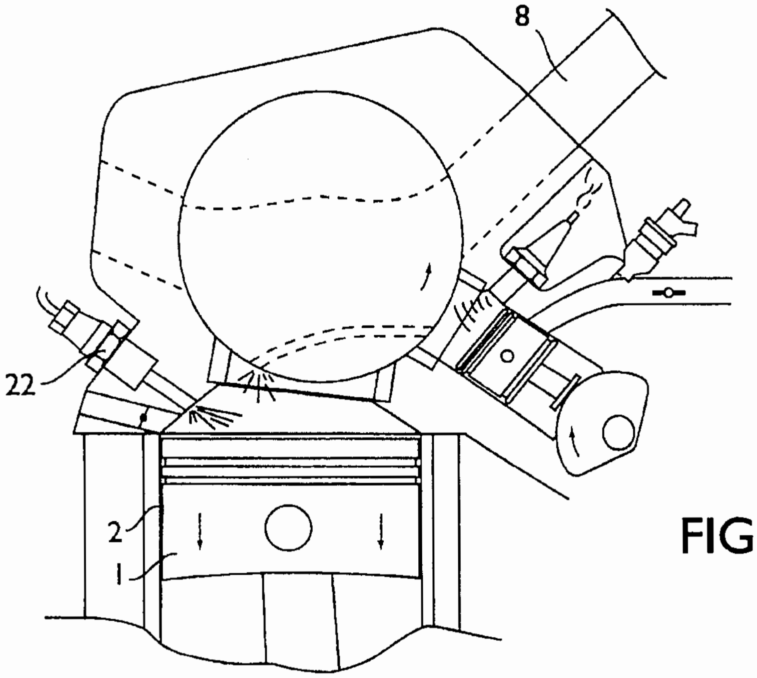


FIG. 8

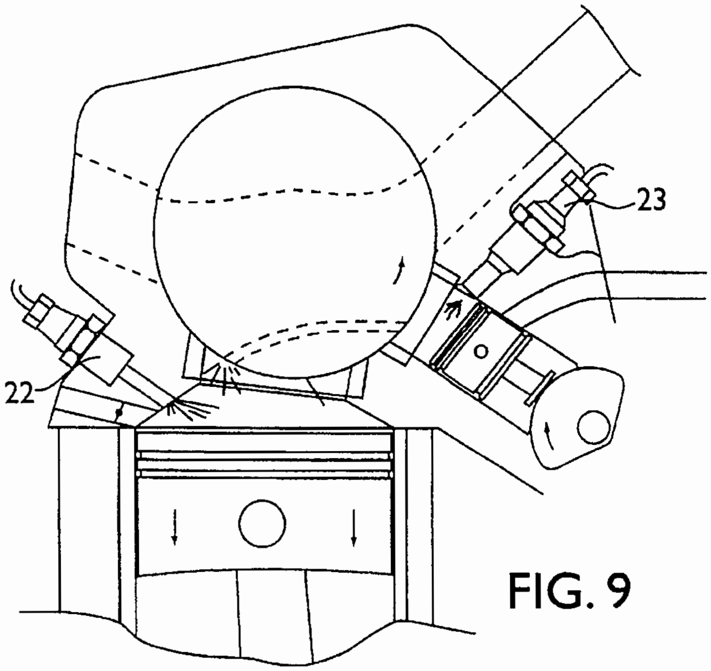


FIG. 9

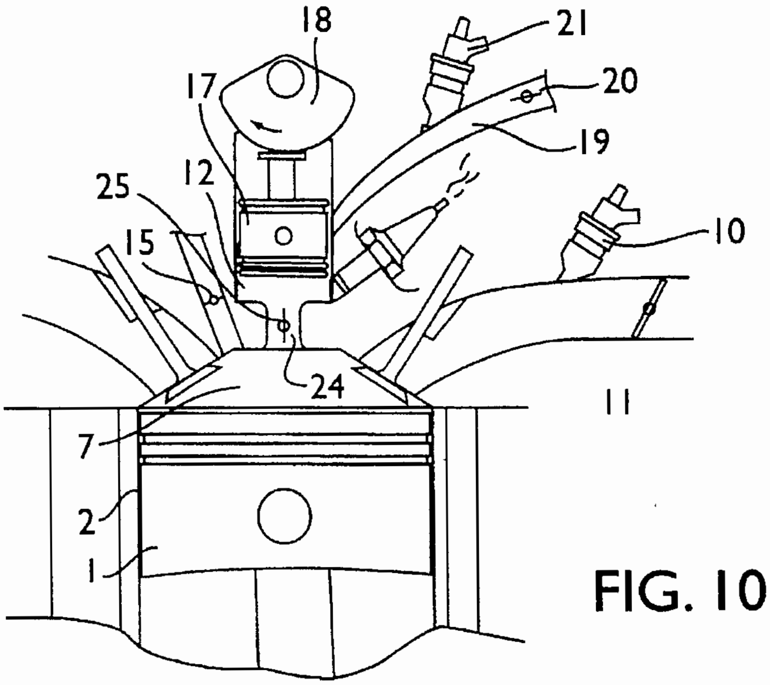


FIG. 10

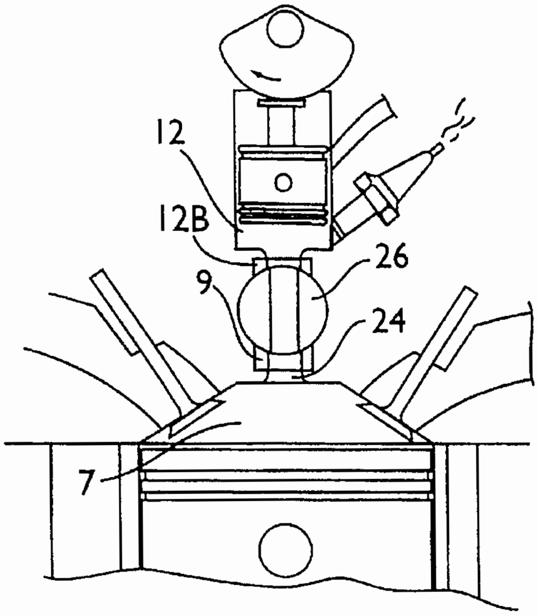


FIG. 11

METHOD AND DEVICES FOR CONTROLLING THE COMBUSTION OF A FOUR STROKE ENGINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a method and devices for controlling the combustion of an internal combustion engine functioning according to a four-stroke cycle with spark or other ignition, with valve timing or equipped with a rotary intake and/or exhaust distributor.

2. Description of Background and Relevant Information

The thermodynamic efficiency of the combustion of internal combustion engines is directly proportional to the gas pressure at the end of the compression stroke and consequently to the load of the engine, itself a function of the opening of the accelerator valve. The specific consumption of the engine is related to the thermodynamic efficiency, which amounts to saying that for a given engine displacement the less torque and/or power required the more the specific consumption increases. This is extremely penalizing especially when the engine equips an automobile because the result is that at low speeds and low loads the fuel consumption is very substantial, and consequently so are the polluting exhaust emissions, but, especially in the city, the engine is always used at a low speed and at low loads. To clarify, an automobile engine that consumes at average or full load, approximately 200 to 250 grams of fuel per horsepower and per hour on the highway sees its consumption in the city increased to approximately 1000 or even 2000 grams of fuel per horsepower and per hour.

Conscious of this problem, motorists sought to improve the consumption at low loads in various manners: either by producing engines with poor or very poor mixtures (in the case of stratified load engines); or by trying to obtain variable compression ratio engines in order to try to increase the pressure at the end of compression; or even by "disengaging" one or more cylinders in order to increase the load on the cylinders that remain in operation, for equivalent power.

The solutions have the disadvantage of only very partially resolving the problem and are in addition in certain cases particularly difficult and onerous to implement.

SUMMARY OF THE INVENTION

The method according to the invention enables the engine to function at weak loads with combustion efficiencies equivalent to those obtained at average or full load. The invention also relates to devices for implementing this method.

During operation of the four-stroke engine, the intake gases, after having been drawn into the cylinder by the piston are compressed in the combustion chamber in order to be ignited therein by the spark plug, thereby increasing in volume and pushing the piston, thus obtaining the power stroke also called explosion or combustion. In practice, the volume of the combustion chamber substantially represents between 9 and 12% of the volume of the cylinder according to the chosen compression ratio. The method according to the invention is characterized by the joining to this assembly of a small secondary combustion chamber entirely separated from the principal chamber and supplied independently and separately with compressed intake gas. During average or full load operation, the gases compressed in this small

secondary chamber are ignited by a spark plug, while shortly before or substantially after the start of this combustion, this small secondary combustion chamber is connected, by the opening of one (or several) linkage channel, the principal combustion chamber where the combustion of gases issuing from the secondary chamber will then ignite (instead of and in place of the spark plug) the intake gases compressed in the principal combustion chamber. The efficiency of this ignition by "flame jet/burst of flames" issued from the combustion of the secondary chamber also enables utilization in the principal chamber of very poor fuel-air mixtures as well as raised compression ratios ensuring a weak fuel consumption.

During the operation of the engine at low loads, the cylinder and the principal combustion chamber are no longer supplied with fuel, but only with air, and the piston is pushed in the principal cylinder only by the explosion of gases contained in the small secondary combustion chamber, through the linkage channel. One easily understands that the small secondary combustion chamber operates almost continuously at full load with a good thermodynamic efficiency, guaranteeing a low consumption of fuel.

During combustion stroke (or explosion) and exhaust stroke, the volume of the small secondary combustion chamber is maintained substantially constant at its small volume, so that all the efficiency of the explosion of gases during combustion serves to push the engine piston of the principal cylinder, as well as to better empty the small secondary combustion chamber during the exhaust stroke.

During low load operation when the principal cylinder and the principal chamber are no longer supplied with fuel, it is particularly interesting, during the intake and compression strokes, to open a valve in the principal combustion chamber, connecting the latter with the atmosphere, with the object of avoiding the pumping efforts during intake and the counter pressure on the piston during the compression stroke that would uselessly absorb the power.

One thus notes that in the method according to the invention, one distinguishes two modes of operation: average/full load operation, low load operation. The operation cycles of an engine cylinder according to the combustion control method according to the invention are thus the following:

1. When the engine is at average or full loads

induction: of air and fuel into the principal cylinder of air and fuel for supplying the small secondary combustion chamber

compression: of the mixtures in the two combustion chambers

ignition: lighting of the mixture in the small chamber by a spark plug

opening: of the linkage channel(s) between the small combustion chamber and the principal combustion chamber, lighting of the mixture in the principal combustion chamber

explosion: of the set of combustions (power stroke) during this cycle the volume of the secondary combustion chamber is maintained at its minimum value

exhaust: of the gases burned in the engine cylinder and in the small secondary combustion chamber. During this cycle the volume of the secondary combustion chamber is also conserved at its minimum value.

2. When the engine is at low loads:

induction: of air alone into the principal cylinder of air and fuel intended to supply the secondary chamber

compression: of the fuel-air mixture in the secondary chamber, opening of the aeration valve of the principal chamber to avoid counter pressure on the piston

- lighting: of the fuel-air mixture in the secondary chamber, closure of the aeration valve of the principal chamber, opening of the linkage channel between the secondary chamber and the principal chamber.
- explosion: of the gases contained in the secondary chamber in the principal cylinder through the linkage channel, during this stroke the volume of the secondary chamber is maintained at its minimum value.
- exhaust: of the combustion gases, during this cycle, the volume of the secondary chamber is also maintained at its minimum value.

The arrangement of the small secondary combustion chamber, the opening mode of the linkage channel(s) between the small secondary combustion chamber and the principal combustion chamber, the methods for supplying and pressurizing the gases in the small secondary combustion chamber, the opening and the closing of the aeration valve can use any appropriate means to obtain the required functions without at all changing the principle of the method of the invention. The volume of the small combustion chamber will be chosen as a function of the characteristics sought during operation at low loads and can vary by several percent from that of the principal combustion chamber until possibly equalling it, without at all changing the principle of the method of the invention.

The method according to the invention applies to internal four-stroke combustion engines with spark or other ignition with one or several cylinders, with cam shaft or valve timing or otherwise, nonetheless it appears that the method according to the invention finds an application more particularly easy to obtain in the case of a rotary timing engine in which the timing rotor will also serve to ensure in its rotation the cycled linkage between the principal combustion chamber and the secondary combustion chamber.

The invention also relates to several devices which can be implemented for the application of the method according to the invention, especially in the case of an engine equipped with rotary timing with a unique lateral transfer port assuring successively the exhaust then the intake, while the body of the distributor obstructs the combustion chamber during the compression stroke and the explosion stroke, characterized by the joining, in another transverse plane, of a small secondary combustion chamber, opening up on the rotary distributor, and supplied, by an independent intake circuit, with a compressed fuel-air mixture by a small piston itself controlled by a cam, enabling during the operation of the engine, induction by the intake circuit independent of that of the principal cylinder, of a fuel-air mixture, compressing it in the small volume of the secondary combustion chamber, and maintaining substantially constant the small volume of this combustion chamber while in the cycle, and after having ignited by means of a spark plug, the mixture in the secondary combustion chamber, the rotary distributor in which is (are) cut one (several) linkage channel(s), goes into its rotation, through this (these) linkage channel(s) connects the two chambers so that on the one hand, during operation at low loads, the gases burned in the secondary chamber explode in the principal chamber which in this case of operation is only supplied with air (without fuel) thus pushing the piston that assures the power stroke, and that, on the other hand, during average or full load operation, the gases burned in the secondary chamber come to ignite the mixture contained in the principal chamber, which, in this case of operation is supplied with a fuel-air mixture and, enables the combustion and the explosion of the gases contained both in the principal chamber and in the secondary chamber pushing the piston and thus assuring the power stroke.

During low load operation, while the cylinder and the principal combustion chamber are only supplied with fresh air without fuel, an electrovalve will open during the induction stroke and compression stroke to connect the principal chamber with the atmosphere, in order to avoid the pumping efforts during induction, and the counter pressure on the piston during the compression stroke, and closes during the explosion stroke and exhaust stroke.

During average or full load operation, this electrovalve always stays closed to enable the normal operation of the cylinder.

An engine equipped according to the method and device according to the invention operate in fact as a small cubic capacity engine when one requires little power (thus at actual full load with good efficiency and little specific consumption) and like a large cubic capacity engine when one needs more power (thus at average or full load with good efficiency and little specific consumption).

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, advantages and characteristics of the invention will appear upon reading the non-limiting description of several embodiments of the invention applied to controlling the combustion of a four-stroke engine, made in reference to the attached drawings wherein:

FIG. **1** schematically represents, seen in a transverse section, a four-stroke engine with spark ignition, with rotary timing, with top dead center ignition, equipped with a device for controlling the combustion according to the method of the invention, in a low load mode of operation.

FIG. **2** represents the same engine at the same moment in the cycle, in the average/full load mode of operation.

FIG. **3** represents this engine during the exhaust stroke.

FIG. **4** represents this engine during the induction stroke in the mode of operation at low loads.

FIG. **5** represents the engine during the induction stroke in the average/full load mode of operation.

FIG. **6** represents the engine during the compression stroke in the low load mode of operation.

FIG. **7** represents the engine during the compression stroke in the average/full load mode of operation.

FIG. **8** schematically represents, seen in a transverse section, a four-stroke rotary distribution engine, equipped with a device for controlling the combustion according to the method of the invention, where the principal combustion chamber operates with heterogeneous mixtures like a diesel engine.

FIG. **9** represents the same engine whereas the principal combustion chamber and the small secondary combustion chamber operate on heterogeneous mixtures.

FIG. **10** represents a device according to the method according to the invention applied to a valve engine.

FIG. **11** represents an inter-chamber blocking device with a rotary slide valve/oscillating cylindrical valve.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The engine schematically represented in FIGS. **1** through **7** comprises elements that are well known in rotary distribution engines, operating according to the four-stroke cycle. A piston **1**, sliding in a cylinder liner **2** is covered by a cylinder head **3** in which is driven, at half speed of the engine, a rotary distributor **4**, with a unique transfer port **5**, which during its rotation (in the direction of the arrow) will successively connect the exhaust conduit **6** and the combustion chamber **7** in order to assure the exhaust stroke, then the combustion chamber **7** with the induction **8** thus assuring the induction stroke, the body of the rotary distributor **4** blocking the combustion chamber **7** during the compression stroke and the combustion or power stroke, the impermeability of the chamber being assured by the sliding element **9**. Supplying the cylinder with fuel is assured by the injector **10**, and the air flow controlling the fuel-air load of the cylinder by the throttle **11**.

FIGS. **1–9** show the engine at different phases of its operation, where, to simplify understanding of the drawings, the transverse section is offset at the level of the combustion chambers **7** and **12**, gasket rings **9** and **12B**, and pistons **1** and **17**, and shows these elements on the same plane whereas in reality they are not on the same transverse plane, while the induction conduit **8**, the transfer port **5** and the exhaust conduit **6** represented by dashed lines are substantially on the same plane as the principal combustion chamber **7** and its gasket ring **9**.

FIG. **1** represents at top dead center ignition a rotary distribution engine such as described above and equipped with a device enabling application of the method according to the invention, in a low load mode of operation, seen in a transverse section (offset at the level of the cylinders) where the compressed fuel-air mixture contained in the small secondary combustion chamber **12**, has just been ignited by the spark plug **13** while the transfer port **14** arranged in the rotary distributor **4** connects the principal or primary combustion chamber **7** with the secondary combustion chamber **12** and the fuel-air mixture ignited in the latter expands through the transfer port **14** into the principal chamber **7** pushing the piston **1** and thus assuring the power stroke at low loads; the gas throttle supplying the principal combustion chamber **7** is closed as well as the aeration electrovalve **15**.

FIG. **2** represents the same engine similarly equipped at the same moment in the cycle but whereas it operates in average/full load mode, the gas throttle **11** is then opened and the injector **10** supplied the chamber during the induction stroke, the "flame jet" from the combustion of the secondary chamber ignites in turn the fuel-air mixture of the principal chamber and the gases contained in the two chambers expand pushing the piston thus assuring the power stroke.

One consequently understands all the advantages of the method as well as of the device above.

The exhaust is carried out normally, FIG. **3** by the exhaust conduit **6** and empties the cylinder, the combustion chamber **7** as well as the secondary combustion chamber **12** through an orifice **16** arranged for that purpose, the secondary piston **17** controlled by a double acting cam **18** (or positive drive control) is maintained substantially at its top dead center to reduce to the maximum the volume to be emptied during this cycle: this cycle is common to the two modes of operation, at low loads, and at average/full loads.

FIG. **4** represents the engine during the induction stroke in a low load mode of operation, the gas throttle **11** is closed, injector **10** is not activated, the aeration valve **15** is open to avoid a pumping brake during the descent of the piston **1**; the secondary piston **17** returned by the cam **18** uncovers the secondary induction circuit **19** to admit the fuel-air mixture dosed by the injector **21**, the fine steering/control of the engine is carried out by means of the secondary gas throttle **20**.

FIG. **5** represents the engine during the induction stroke at a average/full load mode of operation, the gas throttle **11** is open, the injector **10** activated, and the fuel-air mixture is admitted into the cylinder through the transfer port **5** arranged in the rotary distributor **4**; the secondary piston **17** returned by the cam **18** uncovers the secondary admission circuit **19** to admit the fuel-air mixture dosed by the injector **21**, the secondary gas throttle **20** is open, and the aeration electrovalve **15** of the principal combustion chamber **7** is closed.

FIG. **6** represents the engine during the compression stroke in a low load mode of operation, the principal piston **1** carries out its ascendant path whereas the aeration electrovalve **15** is open in order to avoid counter pressures on the piston **1**; the cam **18** pushes the secondary piston **17** to compress the fuel-air mixture in the secondary chamber **12** blocked by the body of the rotary distributor **4**, the impermeability being assured by the sliding ring **12B**. At the end of compression air without fuel is thus found in the principal chamber **7** and a compressed fuel-air mixture in the secondary combustion chamber **12**.

FIG. **7** represents the engine during the compression stroke in the average/full load mode of operation, the principal piston **1** carries out its ascendant course whereas the aeration electrovalve **15** is closed, and compresses the fuel-air mixture in the principal combustion chamber **7**, the impermeability of the chamber is assured by the sliding ring **9**; the cam **18** pushes the secondary piston **17** to compress the fuel-air mixture in the secondary chamber **12** blocked by the body of the rotary distributor **4**, the impermeability being assured by the sliding ring **12B**. At the end of compression, fuel-air mixtures are found in the principal chamber **1** and in the secondary chamber **12**.

The cycle in the low load mode of operation starts again by ignition and explosion such as described in FIG. **1**.

The cycle in the average/full mode of operation starts again by ignition and explosion such as described in FIG. **2**.

The method and the devices according to the invention also apply in the case of engines operating with heterogeneous mixtures, with self ignition more commonly called "diesel" engine, operating with gas oil or other heavy fuels, two cases can be obtained, either a mixed method where the small combustion chamber operates with an ignition controlled by spark plug, whereas the principal cylinder is supplied with gas oil and operates on a heterogeneous mixture, the start of combustion being controlled by the opening of the linkage channel **14**. FIG. **8** shows an engine thus equipped, seen in a transverse section (offset) where a direct fuel injector **22** has been installed in the principal combustion chamber **7**.

In addition, the method and devices according to the invention also apply in the case of engines entirely using a heterogeneous mixture where the small secondary combustion chamber also operates like a diesel engine; FIG. **9** shows an engine thus equipped, seen in a transverse section where a fuel injector **23** has been installed in the secondary combustion chamber **12**.

FIG. **10** represents a device according to the method as per the invention applied to a valve timing engine, a transfer or linkage port **24** is arranged in the upper portion of the principal combustion chamber that it connects to a small secondary combustion chamber **12**, supplied with a compressed fuel-air mixture by a piston **17**, and a secondary induction circuit comprised of a conduit **19**, an injector **21** and a gas throttle **20**; the secondary piston is controlled by a double acting cam **18**. A shutter/plug **25** is positioned in the transfer port **24** and connects, during its cycled opening, the small secondary combustion chamber **12** and the principal combustion chamber 7. The low load and average/full load modes of operation and the course of the cycles are the same as previously described.

FIG. **11** represents, in a valve engine equipped according to the method of the invention a shutter/plug device of the transfer port **24** using a rotary distributor **26** comprising a transfer conduit **27** traversing it, while the impermeability of the principal combustion chamber **7** is assured by a sliding ring **9** and while the impermeability of the small secondary combustion chamber **12** is assured by a sliding ring **12B**. This rotary distributor **26** is driven at one-fourth of the speed of the crankshaft if the gasket rings **9** and **12B** are on the same transverse plane or at half speed if the rings **9** and **12B** are on a different plane and will connect the two combustion chambers substantially at top dead center ignition to enable the operation according to the method as per the invention.

Of course, the present invention is not at all limited to the embodiments described and represented; it is capable of numerous variations accessible to one with ordinary skill in the art, according to the applications envisioned and without departing from the scope of the invention.

I claim:

1. A device for controlling combustion of a four-stroke rotary timing engine, the engine including at least one cylinder and cylinder liner, a primary piston mounted for reciprocation within said cylinder, a primary induction circuit that includes an induction conduit, an exhaust conduit, a primary combustion chamber in which a fuel-air mixture is compressed by the primary piston, the fuel-air mixture being ignited in the primary combustion chamber, and a gasket ring for sealing the primary combustion chamber, said device having a low load mode of operation and a full load mode of operation, said device comprising:

a rotary distributor mounted for rotation on and with respect to the assembly of said cylinder, cylinder liner, piston, primary combustion chamber, and gasket ring;

said rotary distributor having a lateral transfer port for successively connecting said exhaust conduit with said primary combustion chamber and said primary combustion chamber with said induction conduit, said induction conduit, exhaust conduit, and transfer port lying substantially within a common plane;

a secondary combustion chamber, smaller than said primary combustion chamber and lying in a plane different from said common plane, a gasket ring for sealing said secondary combustion chamber with respect to said rotary distributor;

a secondary induction circuit for supplying an independent fuel-air mixture to said secondary combustion chamber, said secondary induction circuit being separate from said primary induction circuit, said secondary induction circuit comprising a secondary induction conduit, fuel injector, and gas throttle;

a secondary piston mounted for compressing said independent fuel-air mixture within said secondary combustion chamber;

means for igniting said independent fuel-air mixture following induction of said fuel-air mixture and compression thereof within said secondary combustion chamber;

said rotary distributor having a linkage channel, separate from said transfer port, for communicating said primary combustion chamber with said secondary combustion chamber for ensuring expansion of an ignited fuel-air mixture from said secondary combustion chamber to said primary combustion chamber to push said primary piston and thus ensure a power stroke of the engine;

means for supplying said primary combustion chamber with only air in said low load mode of operation, said ignited fuel-air mixture in said secondary combustion chamber expanding through said linkage channel to said primary combustion chamber to push said primary piston and thus ensure a power stroke of the engine.

means for supplying said primary combustion chamber with a fuel-air mixture in said full load mode of operation, said ignited fuel-air mixture in said secondary combustion chamber issuing a flame jet from said secondary combustion chamber through said linkage channel to said primary combustion chamber for igniting said fuel-air mixture in said primary combustion chamber, whereby expansion of gases of combustion from said secondary combustion chamber and said primary combustion chamber expand and push said primary piston and thus ensure a power stroke of the engine.

2. A device according to claim **1**, wherein:

said rotary distributor further comprises an exhaust orifice for communicating said secondary combustion chamber with said exhaust conduit during said exhaust stroke;

the device further comprises a double-acting drive cam control for said secondary piston for compressing said fuel-air mixture in said secondary combustion chamber, said cam control comprising means for maintaining said secondary piston at a top dead center position during compression, power, and exhaust strokes, and for maintaining said piston at a bottom dead center position during an induction stroke for enabling induction of said independent fuel-air mixture.

3. A device according to claim **1**, further comprising:

an aeration valve movable between an open position and a closed position within an aeration orifice in communication with said primary combustion chamber, said aeration valve being positionable in the closed position in said full load mode of operation and positionable in the open position during said induction stroke and said compression stroke in said low load mode of operation for aeration of said primary combustion chamber.

4. A device according to claim **1**, wherein:

said secondary induction circuit comprises a direct injector for supplying said secondary combustion chamber with a heterogeneous fuel-air mixture.

5. A device according to claim **1**, wherein:

said primary induction circuit comprises a direct injector for supplying said primary combustion chamber with a heterogeneous fuel-air mixture and a fuel circuit under pressure.

6. A device according to claim **4**, wherein:

said primary induction circuit comprises a direct injector for supplying said primary combustion chamber with a heterogeneous fuel-air mixture and a fuel circuit under pressure.

7. A device according to claim **1**, wherein:

said means for igniting said independent fuel-air mixture within said secondary combustion chamber comprises a spark plug.

8. A four-stroke engine comprising the device according to claim **1** for controlling combustion.

9. A device for controlling combustion of a four-stroke valve timing engine, the engine including at least one cylinder and cylinder liner, a primary piston mounted for reciprocation within said cylinder, a primary induction circuit that includes an induction conduit and an intake valve therein, an exhaust conduit and an exhaust valve therein, a primary combustion chamber in which a fuel-air mixture is compressed by the primary piston, the fuel-air mixture being ignited in the primary combustion chamber, said device having a low load mode of operation and a full load mode of operation, said device comprising:

a secondary combustion chamber, smaller than said primary combustion chamber;

a linkage port positioned above said primary combustion chamber, said linkage port communicating said primary combustion chamber with said secondary combustion chamber;

means for controlling communication between said primary combustion chamber and said secondary combustion chamber through said linkage port;

a secondary induction circuit for supplying an independent fuel-air mixture to said secondary combustion chamber, said secondary induction circuit being separate from said primary induction circuit, said secondary induction circuit comprising a secondary induction conduit, fuel injector, and gas throttle;

a secondary piston mounted for compressing said independent fuel-air mixture within said secondary combustion chamber;

means for igniting said independent fuel-air mixture following induction of said fuel-air mixture and compression thereof within said secondary combustion chamber;

said linkage port ensuring expansion of an ignited fuel-air mixture from said secondary combustion chamber to said primary combustion chamber to push said primary piston and thus ensure a power stroke of the engine;

means for supplying said primary combustion chamber with only air in said low load mode of operation, said ignited fuel-air mixture in said secondary combustion chamber expanding through said linkage port to said primary combustion chamber to push said primary piston and thus ensure a power stroke of the engine;

means for supplying said primary combustion chamber with a fuel-air mixture in said full load mode of operation, said ignited fuel-air mixture in said secondary combustion chamber issuing a flame jet from said secondary combustion chamber through said linkage port to said primary combustion chamber for igniting said fuel-air mixture in said primary combustion chamber, whereby expansion of gases of combustion from said secondary combustion chamber and said primary combustion chamber expand and push said primary piston and thus ensure a power stroke of the engine.

10. A device according to claim **9**, wherein:

said means for controlling communication between said primary combustion chamber and said secondary combustion chamber comprises a shutter valve positioned within said linkage port.

11. A device according to claim **9**, wherein:

said means for controlling communication between said primary combustion chamber and said secondary combustion chamber comprises a rotary distributor, said rotary distributor having a rotatable transfer conduit therein for enabling cycled opening and closing of said linkage port between said primary combustion chamber and said secondary combustion chamber.

12. A device according to claim **11**, further comprising:

a first gasket ring for sealing said rotary distributor with said primary combustion chamber; and

a second gasket ring for sealing said rotary distributor with said secondary combustion chamber.

13. A device according to claim **12**, wherein:

the engine includes a crankshaft;

said first gasket ring and said gasket ring are positioned along a common transverse plane; and

said rotary distributor is driven by the crankshaft at one-fourth speed of the crankshaft in two directions.

14. A device according to claim **12**, wherein:

the engine includes a crankshaft;

said first gasket ring and said gasket ring are positioned along different transverse planes; and

said rotary distributor is driven by the crankshaft at one-half speed of the crankshaft in a single direction.

15. A device according to claim **9**, wherein:

said secondary induction circuit comprises a direct injector for supplying said secondary combustion chamber with a heterogeneous fuel-air mixture.

16. A device according to claim **9**, wherein:

said primary induction circuit comprises a direct injector for supplying said primary combustion chamber with a heterogeneous fuel-air mixture and a fuel circuit under pressure.

17. A device according to claim **15**, wherein:

said primary induction circuit comprises a direct injector for supplying said primary combustion chamber with a heterogeneous fuel-air mixture and a fuel circuit under pressure.

18. A device according to claim **9**, wherein:

said means for igniting said independent fuel-air mixture within said secondary combustion chamber comprises a spark plug.

19. A four-stroke engine comprising the device according to claim **9** for controlling combustion.

20. A method of controlling combustion in a four-stroke engine, the engine including at least one cylinder, a primary piston mounted for reciprocation within said cylinder, a primary induction circuit that includes an induction conduit, an exhaust conduit, a primary combustion chamber, a secondary combustion chamber, smaller than said primary combustion chamber, a secondary cylinder, a secondary induction circuit for supplying an independent secondary fuel-air mixture to said secondary cylinder, said secondary induction circuit being separate from said primary induction circuit, said secondary induction circuit comprising a secondary induction conduit, fuel injector, and gas throttle, a secondary piston mounted within said secondary cylinder for compressing said secondary fuel-air mixture within said secondary combustion chamber, means for igniting said secondary fuel-air mixture following induction and compression thereof within said secondary combustion chamber, said method comprising the steps of:

inducing said secondary fuel-air mixture into said secondary cylinder, the engine including a low load mode of operation in which no fuel is induced into said primary combustion chamber during said step of inducing said secondary fuel-air mixture into said secondary cylinder;

compressing said secondary fuel-air mixture in said secondary compression chamber;

igniting said secondary fuel-air mixture during compression thereof; and opening a linkage channel between said secondary combustion chamber and said primary combustion chamber following said steps of inducing and compressing said secondary fuel-air mixture shortly before or substantially concurrently with the step of igniting said secondary fuel-air mixture, whereby gases ignited in said secondary combustion chamber explode in said secondary combustion chamber and in said primary combustion chamber through said linkage channel, said step of opening the linkage channel between said secondary combustion chamber and said primary combustion chamber comprises ensuring a power stroke for said primary piston solely by means of explosion of said secondary fuel-air mixture.

21. A method according to claim **20**, wherein:

the engine further includes a full load mode of operation comprising the step of inducing into said primary combustion chamber a primary fuel-air mixture during said step of inducing said secondary fuel-air mixture into said secondary cylinder;

said step of opening the linkage channel between said secondary combustion chamber and said primary combustion chamber comprises ensuring a power stroke for said primary piston by means of explosion of said secondary fuel-air mixture and by means of ignition and explosion of said primary fuel-air mixture caused by a flame jet issuing from said explosion of said secondary fuel-air mixture.

22. A method according to claim **20**, wherein:

said primary piston is reciprocated through an induction stroke, a compression stroke, a power stroke, and an exhaust stroke;

said method further comprises the step of maintaining a minimum volume of said secondary combustion chamber during said compression stroke, said power stroke, and said exhaust stroke so that explosion of said secondary fuel-air mixture during combustion is efficiently utilized for pushing said primary piston during said power stroke and for exhausting said secondary combustion chamber during said exhaust stroke.

23. A method according to claim **21**, wherein the engine further comprises an aeration valve movable between an open position and a closed position within an aeration orifice in communication with said primary combustion chamber, said method further comprising:

during said low load mode of operation in which no fuel is induced into said primary combustion, opening said aeration valve during said induction stroke and during said compression stroke.

24. A method according to claim **23**, wherein:

at all times during said full load mode of operation, maintaining said aeration valve closed.

25. A method according to claim **20**, wherein:

said secondary induction circuit comprising a direct injector; and

the step of inducing said secondary fuel-air mixture into said secondary cylinder comprises supplying said secondary cylinder with a heterogeneous fuel-air mixture.

26. A method according to claim **21**, wherein:

said primary induction circuit comprising a direct injector; and

the step of inducing into said primary combustion chamber a primary fuel-air mixture comprises supplying said primary cylinder with a heterogeneous fuel-air mixture.

27. A method according to claim **25**, wherein:

said primary induction circuit comprising a direct injector; and

the step of inducing into said primary combustion chamber a primary fuel-air mixture comprises supplying said primary cylinder with a heterogeneous fuel-air mixture.

28. A method according to claim **20**, wherein:

the step of igniting said secondary fuel-air mixture within said secondary combustion chamber is done by means of a spark plug.

* * * * *

US006094915A

United States Patent [19]

Negre et al.

[11] **Patent Number: 6,094,915**

[45] **Date of Patent: Aug. 1, 2000**

[54] **METHOD AND DEVICES FOR ELIMINATING THE POLLUTION OF CYCLIC INTERNAL COMBUSTION ENGINES WITH AN INDEPENDENT COMBUSTION CHAMBER**

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[21] Appl. No.: **08/913,057**

[22] PCT Filed: **Mar. 4, 1996**

[86] PCT No.: **PCT/FR96/00335**

§ 371 Date: **Sep. 5, 1997**

§ 102(e) Date: **Sep. 5, 1997**

[87] PCT Pub. No.: **WO96/27737**

PCT Pub. Date: **Sep. 12, 1996**

[30] **Foreign Application Priority Data**

Mar. 6, 1995 [FR] France 95 02838

[51] **Int. Cl.**^{7} **F07B 75/02**; F02G 3/02

[52] **U.S. Cl.** **60/712**; 60/39.6; 123/22

[58] **Field of Search** 60/39.6, 712; 123/22

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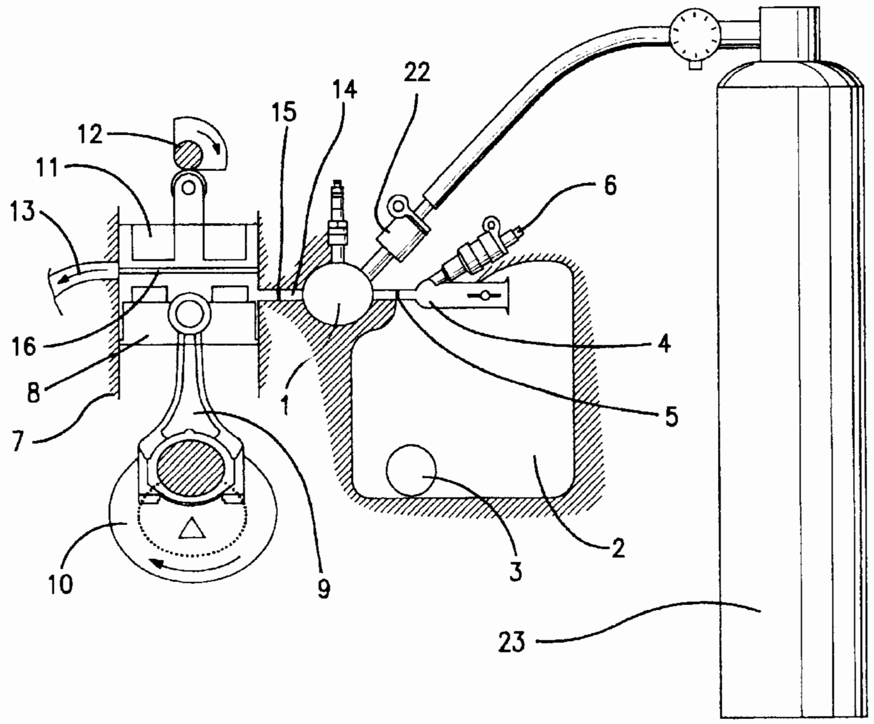
Primary Examiner—Michael Koczo
Attorney, Agent, or Firm—Young & Thompson

[57] **ABSTRACT**

A pollution control method and related devices for cyclical internal combustion engines having a separate combustion chamber **(1)**, wherein the compression chamber, the combustion chamber **(1)** and the expansion chamber **(16)** consist of three separate and entirely self-contained portions. During low-power operation, e.g. in urban traffic, the fuel injector **(6)** is no longer controlled during filling of the combustion chamber, whereby the combustion chamber is filled with high-temperature pure compressed air at each cycle. A small amount of additional air from an outer tank **(23)** for storing highly pressurized air at room temperature is fed into the combustion chamber substantially after the intake of compressed air from the engine compressor, and heated as it contacts the hot compressed air already present in the combustion chamber **(1)**, whereafter it expands and increases the starting pressure to enable effective work to be produced during expansion.

5 Claims, 3 Drawing Sheets



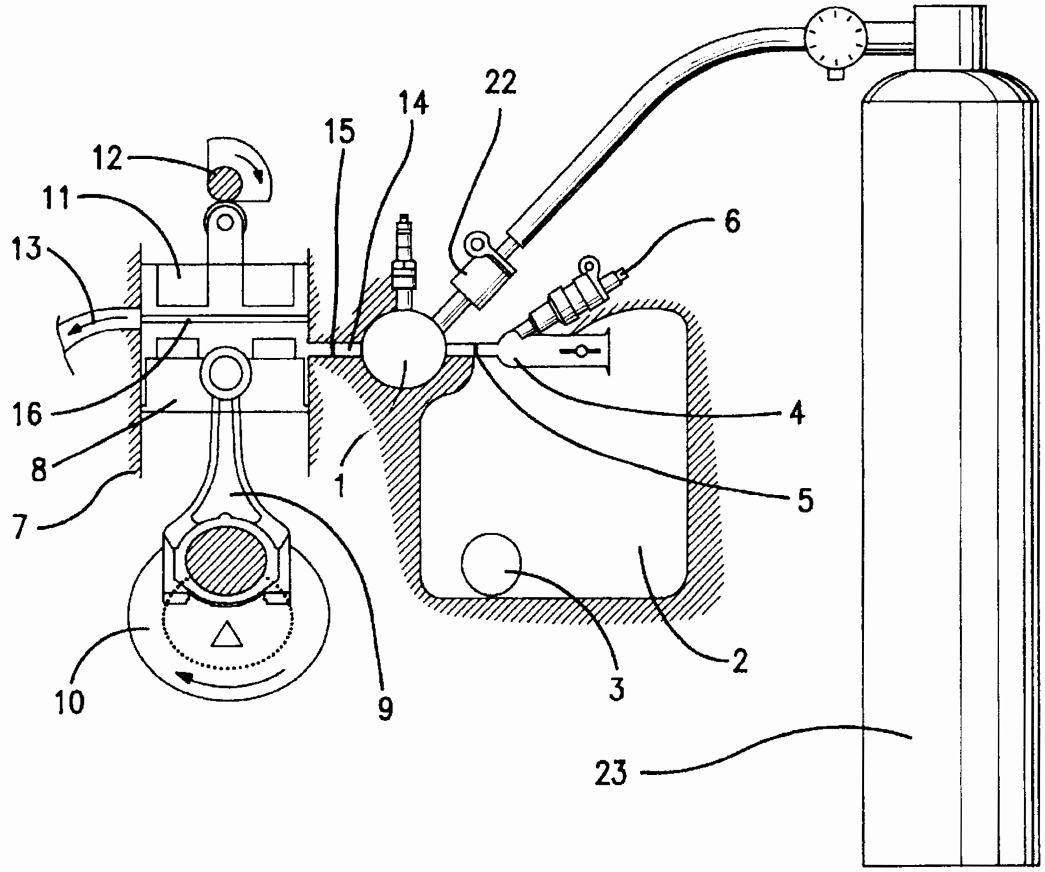


FIG. 1

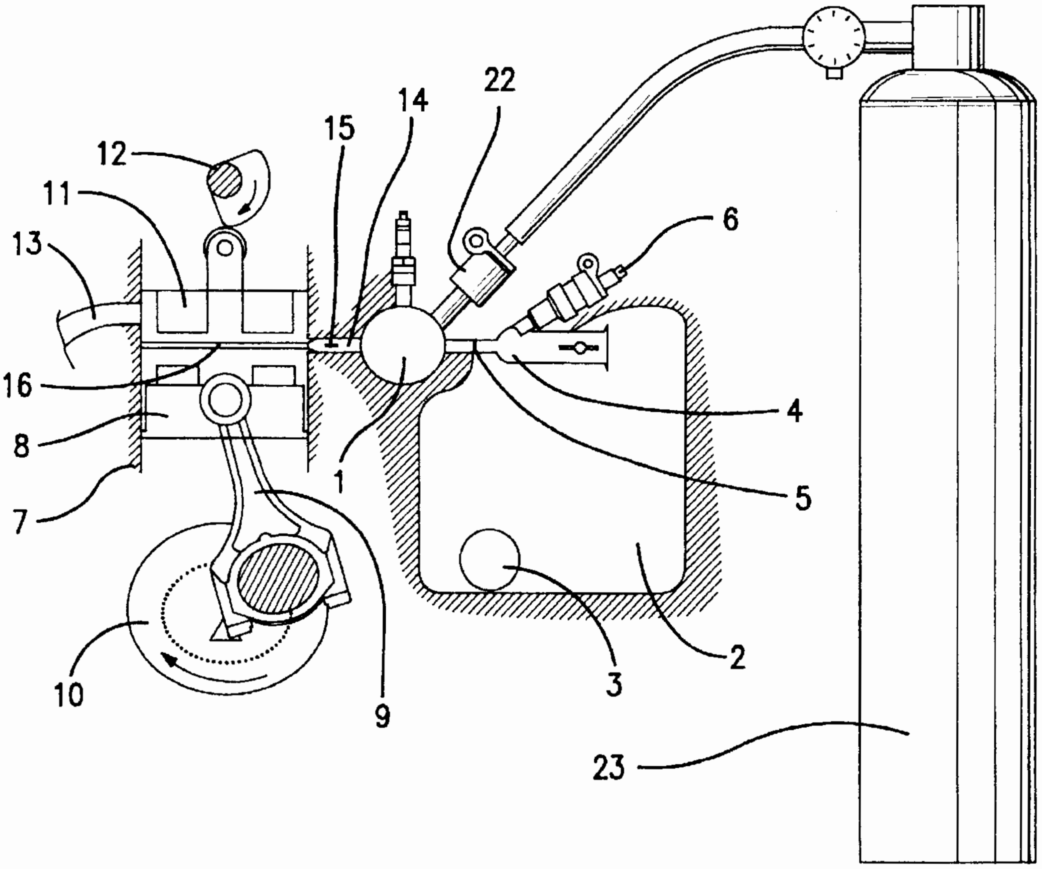


FIG. 2

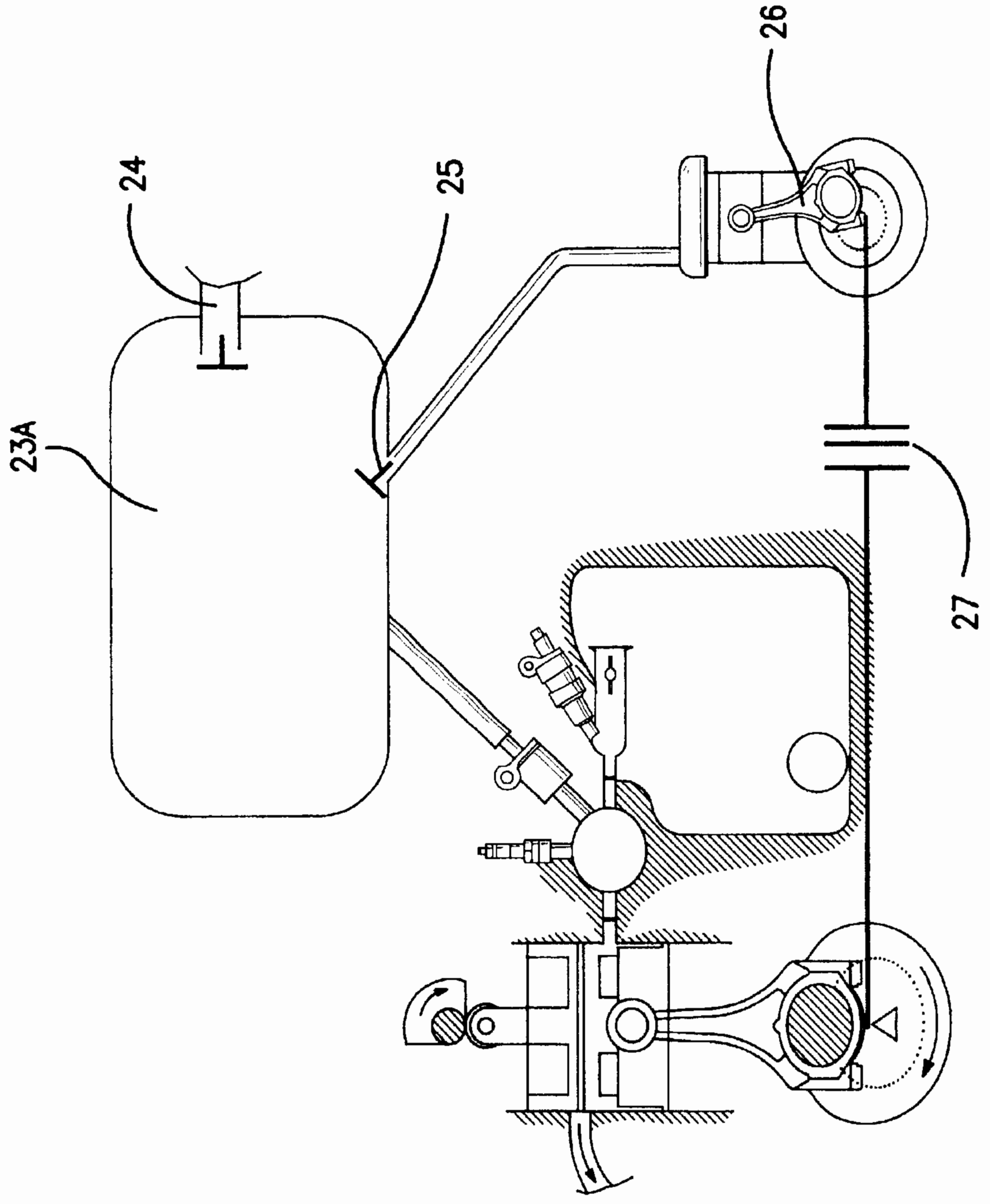


FIG. 3

METHOD AND DEVICES FOR ELIMINATING THE POLLUTION OF CYCLIC INTERNAL COMBUSTION ENGINES WITH AN INDEPENDENT COMBUSTION CHAMBER

CROSS REFERENCE TO RELATED APPLICATIONS

This application is the 35 USC 371 national stage of PCT/FR96/00335 filed on Mar. 4, 1996, which designated the United States of America.

FIELD OF THE INVENTION

The invention relates to a method and to devices for reducing the pollution of cyclic internal combustion engines with constant-volume independent combustion chambers.

BACKGROUND OF THE INVENTION

In his French patent applications with national registration numbers 9501518 and 9502212, the author has described a cyclic internal combustion engine method, the engine having a constant-volume independent combustion chamber, in which the compression chamber, the combustion chamber and the expansion chamber consist of three separate and entirely independent parts, thus allowing each of the three elements to be adapted to suit the function assigned to it without interfering with one another, as well as a system for controlling expansion (9502212) that makes it possible to make the maximum expansion pressure coincide with a crank angle that gives a high tangential force, further improving the overall efficiency of this type of engine.

However, when running in urban areas, especially with cars, the engine still consumes fuel which means that there are still polluting emissions even though these are very substantially reduced.

SUMMARY OF THE INVENTION

The method according to the invention makes it possible to eliminate entirely these emissions of polluting gases, especially in town driving when the engine requires little power.

It is characterized by the implementation means, and more particularly by the fact that during running at low power, the fuel injector is no longer operated and that in this case, any appropriate means are used to introduce into the combustion chamber substantially after the compressed air (without fuel) from the engine compressor has been let into this chamber—a small amount of additional air from an external reservoir in which air (or any other gas) is stored at very high pressure; this small amount of compressed air at ambient temperature will heat up when it comes into contact with the mass of hot air contained in the combustion chamber, will expand and will substantially increase the pressure that there is in the combustion chamber, so that as it expands it will be able to produce a power stroke sufficient to allow, for example, a vehicle to run in town driving mode. The amount of power produced will depend on the amount of additional air injected.

It is also characterized by the fact that the engine is equipped with a high-pressure compressor, which will be engaged during slowing down or during running at high power, in order to allow the external reservoir to be replenished with compressed air at very high pressure, thus making it possible to improve the range in eliminated-pollution running.

Thus the present invention relates to a method for eliminating the pollution of a cyclic internal combustion engine with a constant-volume independent combustion chamber, in which the compression chamber, the combustion chamber and the expansion chamber consist of three separate and entirely independent parts. This allows each of the three elements to be adapted to suit the function assigned to it without interfering with one another, where combustion takes place in an isolated constant-volume independent chamber which may also be equipped with a system for controlling the expansion making it possible to improve the efficiency of the engine. The method is characterized in that during running at low power, for example urban driving, for a vehicle thus equipped:

- the fuel injector is no longer operated during the filling of the constant-volume combustion chamber and the latter is therefore filled with compressed pure air at high temperature during each cycle;
- any appropriate means are used to introduce into the combustion chamber—substantially after the compressed air from the engine compressor has been let in—a small amount of additional air (or any other gas) from an external reservoir in which air (or such other gas) is stored at a very high pressure, at ambient temperature, and allowed to expand to a pressure slightly higher than the pressure in the combustion chamber in order to allow it to be transferred thereto;
- this small amount of additional air will heat up when it comes into contact with the hot compressed air already contained in the combustion chamber, will expand and will substantially increase the initial pressure that there is in the combustion chamber, so that as it expands it will be able to produce an adequate power stroke.

The engine is fitted with an auxiliary high-pressure compressor which will be switched on as the vehicle slows down or brakes, as well as during running at high power when the fuel injector is operated, thus making it possible to improve the range in eliminated-pollution running.

It will now be possible to understand the operation of the engine according to the invention which will thus be able to run at low power, in urban areas, without emitting polluting gases and will be capable instantaneously, on demand, of producing power compatible with normal use on the highway by operating the fuel injector and ceasing to operate the additional-air injector.

The amount of additional air injected, the injection means, the method of storing the compressed air, the gas used, the means of filling the storage reservoir—by on-board compressor operating during deceleration and braking or when running along the highway, and/or from a pump in specially equipped service stations or alternatively by replacing the storage bottle—can vary without in any way altering the principle of the invention.

The invention is quite particularly applicable to cyclic internal combustion engines with a constant-volume independent combustion chamber, especially for urban use in vehicles as well as for any other engine application. It also applies to conventional internal combustion engines.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, advantages and features of the invention will become clear from reading the nonlimiting description of several embodiments given with respect to the appended drawings in which:

FIG. 1 depicts, viewed in cross section, one embodiment of the invention applied to an internal combustion engine with a constant-volume independent combustion chamber with the main piston at top dead center at the end of the exhaust stroke.

FIG. 2 depicts this same engine at the beginning of the expansion stroke.

FIG. 3 depicts a functional drawing of an installation in a vehicle.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. 1 and 2 depict an embodiment of the method according to the invention, applied to a cyclic internal combustion engine with a constant-volume independent combustion chamber where the combustion chamber **1** is fed from a buffer volume **2** of compressed air kept at a more or less constant pressure, this volume itself being fed from a compressor through a pipe **3**. A pipe **4**, the opening and closing of which are controlled by a flap **5**, connects the buffer volume **2** to the independent combustion chamber **1** and contains a fuel injector **6** intended to produce the air/fuel mixture substantially before this mixture is introduced into the combustion chamber **1** where it will be ignited.

An expansion cylinder **7** is equipped with a main piston **8** connected by a connecting rod **9** to the wrist pin of a crankshaft **10**, and with an opposed secondary piston **11**, the motion of which here is controlled by a cam **12**—itself driven off the crankshaft **10**—in such a way that it will accompany the main piston **8** over part of its downstroke so as to make the start-of-expansion pressure—as soon as the flap **15** opens the duct **14** which connects the combustion chamber to the expansion chamber **16**—in a minimum volume, coincide with a crank angle and connecting rod angle of inclination which give the optimum expansion mean tangential force.

An injector **22** of additional compressed air, according to the invention, is fitted in the combustion chamber **1** and is fed, through a pressure-reducing valve, from a bottle **23** that stores compressed air (or any other compatible gas) at high pressure.

During low-power running, according to the invention, when the engine is at top dead center in the expansion cylinder (FIG. 1), the combustion chamber **1** has just been isolated and contains a mass of pure, fuel-free, hot, compressed air the fuel injector **6** will not be operated. The additional-air injector **22** is open and introduces into the combustion chamber a small amount by mass of additional air at ambient temperature coming from the high-pressure storage bottle **23** and expanded to a pressure slightly higher than the pressure in the combustion chamber, so as to allow transfer; this mass of additional air will heat up when it comes into contact with the compressed air contained in the combustion chamber, will expand and will substantially increase the initial pressure so as to produce a power stroke by expanding in the expansion chamber once the duct **14** opens (FIG. 2). On account of the excellent efficiency of the engine unit depicted, the amount of additional air will be very small and will determine the amount of power produced.

The means of injecting additional air into the combustion chamber can vary without altering the principle of the invention, but an electromechanical injector like the fuel injectors is preferred, as it will be possible to control it more readily, particularly as regards its flow rate, using the onboard electronics.

FIG. 3 depicts a functional diagram of an installation of the method according to the invention in a vehicle, where the reservoir for storing compressed additional air at high pressure **23A** is equipped on the one hand with a filler orifice **24** for filling "at the pump" and also with an auxiliary filler orifice **25** fed by a small on-board high-pressure compressor **26** which will be set in operation by a clutch system **27** during deceleration and braking, thus giving the vehicle excellent engine braking, and also when running on the highway at high power. The advantage of this arrangement is that it considerably increases the range in eliminated-pollution running.

It goes without saying that the design of the reservoir, of the air injector, of the high-pressure compressor, of its clutch, of the filler valves and other non-return valves, can vary without in any way altering the principle of the invention which is not in any way restricted to the embodiments described and depicted and can be varied in many ways within the competence of those skilled in the art to suit the considered applications without in any way departing from its spirit.

We claim:

1. Apparatus for reducing pollution of a cyclic internal combustion engine, comprising:
   - a constant volume independent combustion chamber fluidly connected to a buffer volume of compressed air via a pipe, said buffer volume being fluidly connected to a compressor;
   - a first flap positioned in said pipe for controlling the opening and closing thereof;
   - a fuel injector structured and arranged to produce an air/fuel mixture before introducing said mixture into the combustion chamber;
   - an expansion chamber equipped with a main piston connected to a crank shaft, and with a secondary piston mounted in opposition;
   - said expansion chamber being fluidly connected to the combustion chamber via a duct having a second flap positioned in said duct;
   - the movement of said secondary piston being controlled to accompany the main piston over part of its downstroke so as to make the start of expansion pressure, in a minimum volume, coincide with a crank angle and connecting rod angle of inclination, which produce an optimum expansion mean tangential force; and
   - an air injector fluidly connected to the combustion chamber and to a source of highly pressurized compressed air;
   - means for actuating said air injector during low power operation, when operation of said fuel injector is discontinued, and after a charge of hot compressed air contained in the buffer volume has been admitted into the combustion chamber, whereby actuation of said air injector lets a small amount of compressed air contact said hot air, expand, and increase in pressure to produce a power stroke.

2. Apparatus according to claim 1, wherein the source of highly pressurized compressed air comprises a reservoir having a filler orifice with a non-return valve.

3. Apparatus according to claim 1, wherein the source of highly pressurized compressed air comprises a storage reservoir having an auxiliary filler orifice fed by a high pressure on-board compressor structured and arranged to be set in operation by a clutch during deceleration or braking of the vehicle.

4. Method for reducing pollution of a cyclic internal combustion engine, comprising:
   - providing a constant volume independent combustion chamber fluidly connected to a buffer volume of com-

pressed air via a pipe, said buffer volume being fluidly connected to a compressor;

controlling the opening and closing of said pipe by providing a first flap positioned in said pipe;

providing a fuel injector structured and arranged to produce an air/fuel mixture;

introducing said mixture into the combustion chamber;

providing an expansion chamber equipped with a main piston connected to a crank shaft, and with a secondary piston mounted in opposition; said expansion chamber being fluidly connected to the combustion chamber via a duct;

controlling movement of said secondary piston to accompany the main piston over part of its downstroke so as to make the start of expansion pressure, in a minimum volume, coincide with a crank angle and connecting rod angle of inclination which produce an optimum expansion mean tangential force;

providing an air injector fluidly connected to the combustion chamber and to a source of highly pressurized compressed air;

actuating said air injector during low power operation, when operation of said fuel injector is discontinued, and after a charge of hot compressed air contained in the buffer volume has been admitted into the combustion chamber, to let a small amount of compressed air contact said hot air, expand and increase in pressure to produce a power stroke.

5. The method according to claim **4**, wherein the engine is fitted with an auxiliary high-pressure compressor which will be switched on as the vehicle slows down or brakes, as well as during running at high power when the fuel injector is operated, thereby making it possible to improve the range in a limited-pollution running.

* * * * *

US006305171B1

(12) **United States Patent**
Negre et al.

(10) **Patent No.:** **US 6,305,171 B1**
(45) **Date of Patent:** **Oct. 23, 2001**

(54) **METHOD AND DEVICE FOR ADDITIONAL THERMAL HEATING FOR MOTOR VEHICLE EQUIPPED WITH POLLUTION-FREE ENGINE WITH ADDITIONAL COMPRESSED AIR INJECTION**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/582,220**
(22) PCT Filed: **Jan. 22, 1999**
(86) PCT No.: **PCT/FR99/00126**
§ 371 Date: **Jul. 20, 2000**
§ 102(e) Date: **Jul. 20, 2000**
(87) PCT Pub. No.: **WO99/37885**
PCT Pub. Date: **Jul. 29, 1999**

(30) **Foreign Application Priority Data**

Jan. 22, 1998 (FR) 98 00877

(51) **Int. Cl.**^{7} **F01K 7/34**
(52) **U.S. Cl.** **60/653**; 60/668; 60/39.6
(58) **Field of Search** 60/645, 653, 654, 60/668, 39.6

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(74) *Attorney, Agent, or Firm*—Jacobson Holman, PLLC

(57) **ABSTRACT**

The invention concerns a method for additional thermal heating for motor vehicle equipped with pollution-free engine operating with additional compressed air injection into the combustion chamber (**2**) and having high pressure compressed air storage reservoir (**23**). The high pressure compressed air contained in the reservoir is previously to its final use at a lower pressure, directed towards a thermal heater (**56**) to increase its pressure and/or volume before it is injected into the combustion or expension chamber (2). The invention is applicable to all engines equipped with compressed air injection.

11 Claims, 4 Drawing Sheets

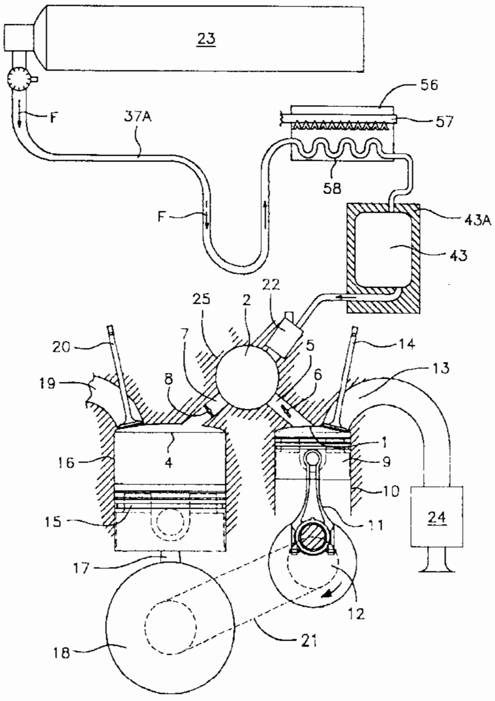

FIG. 1

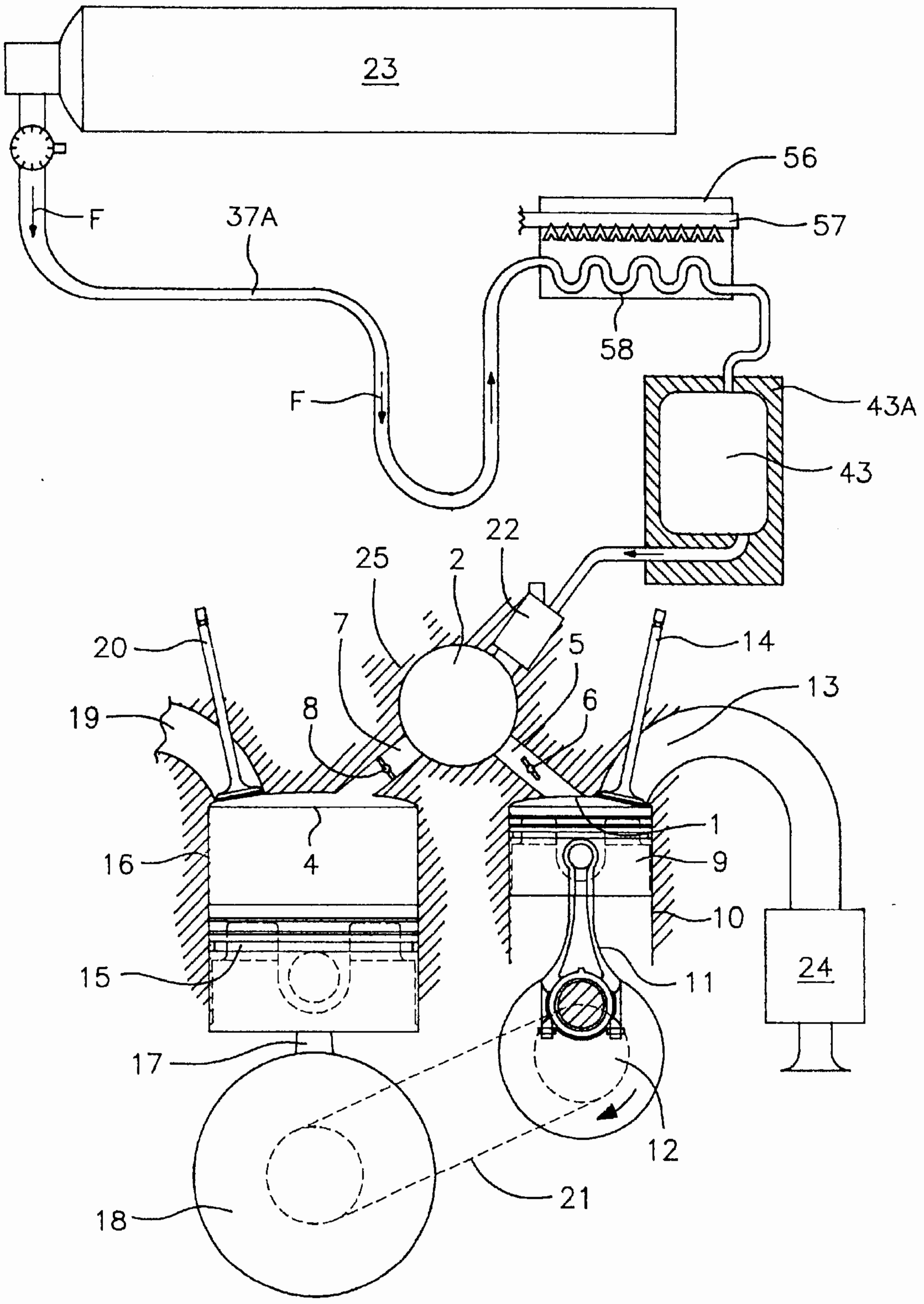
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FIG. 2

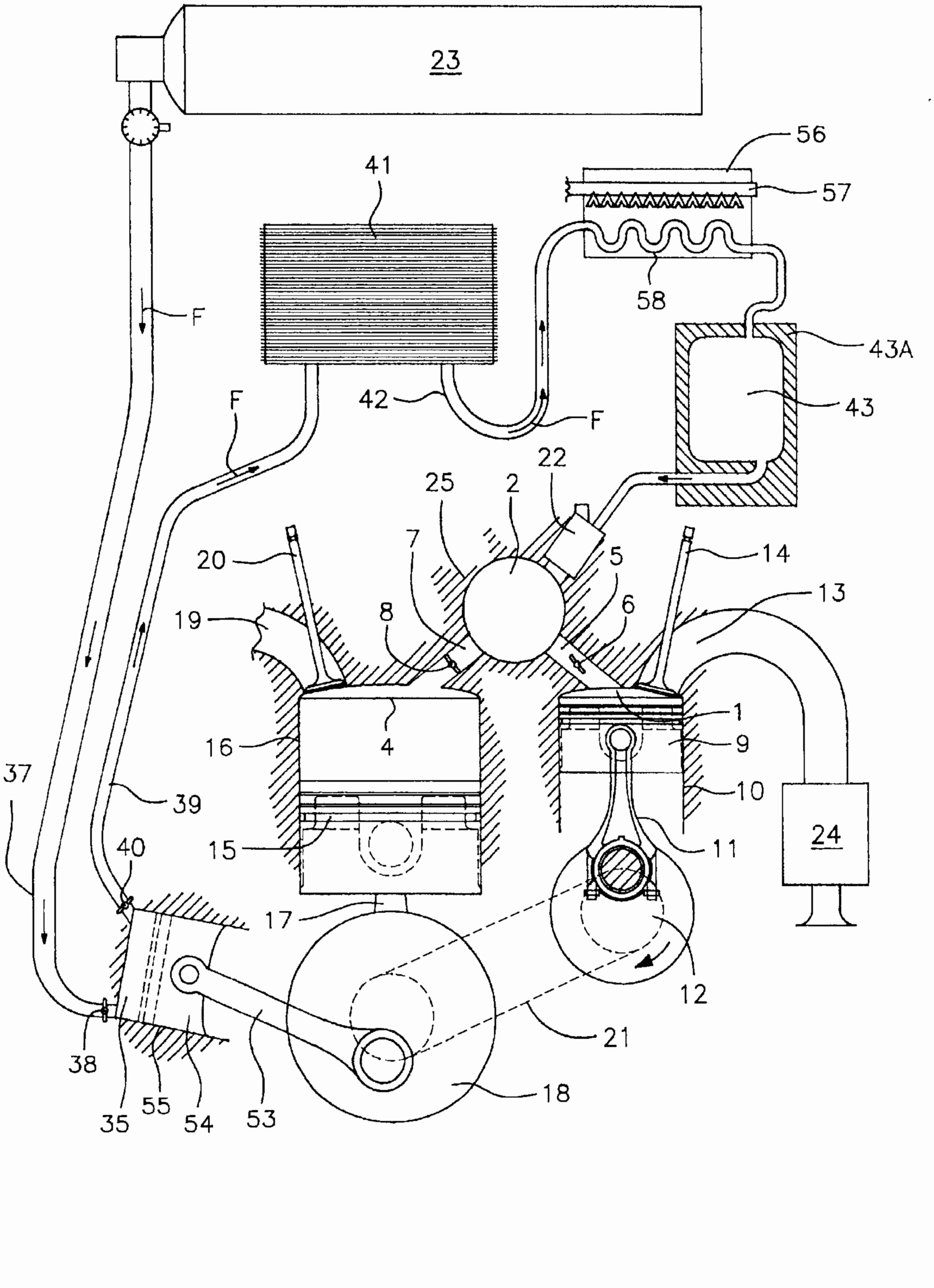
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FIG. 3

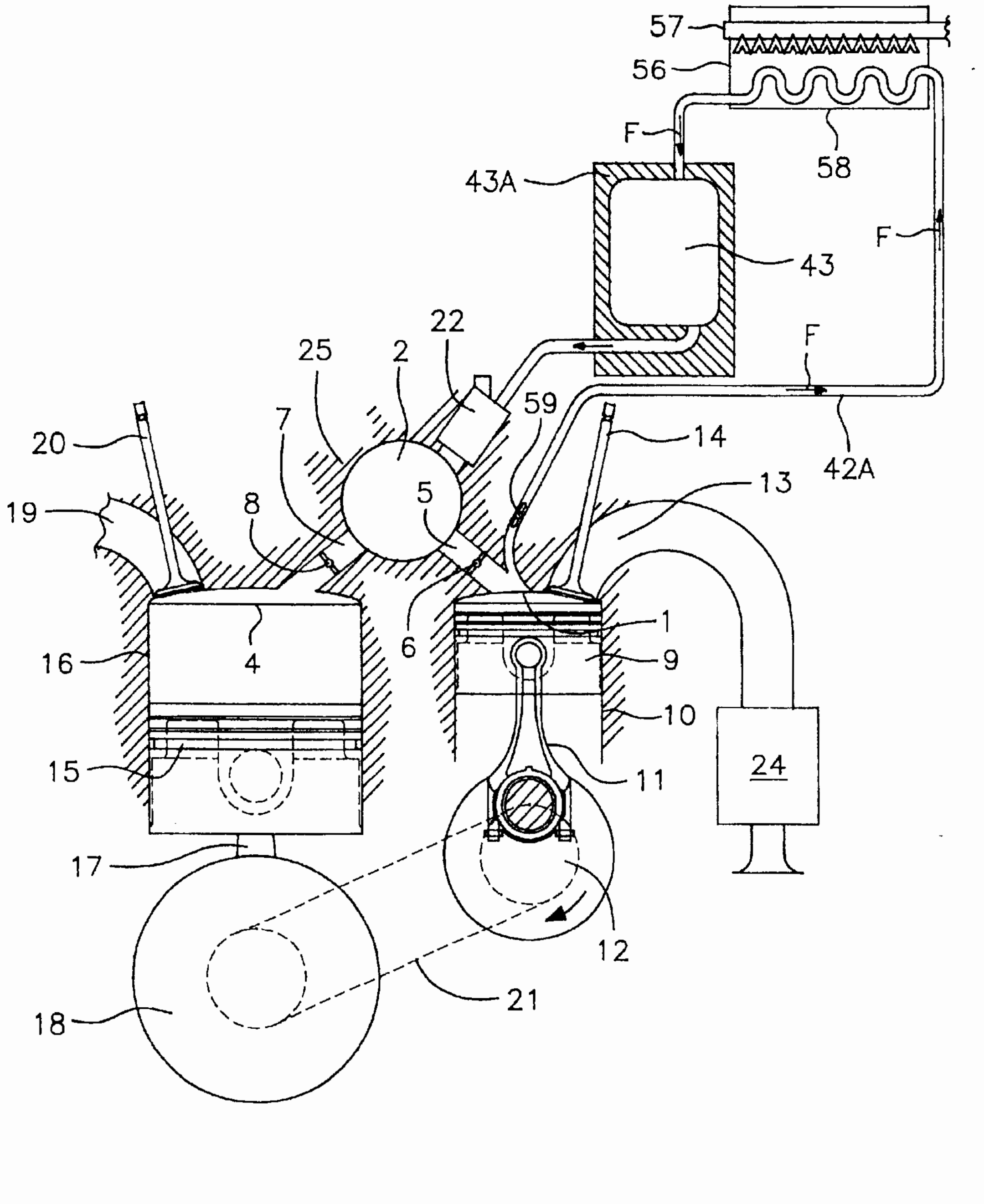
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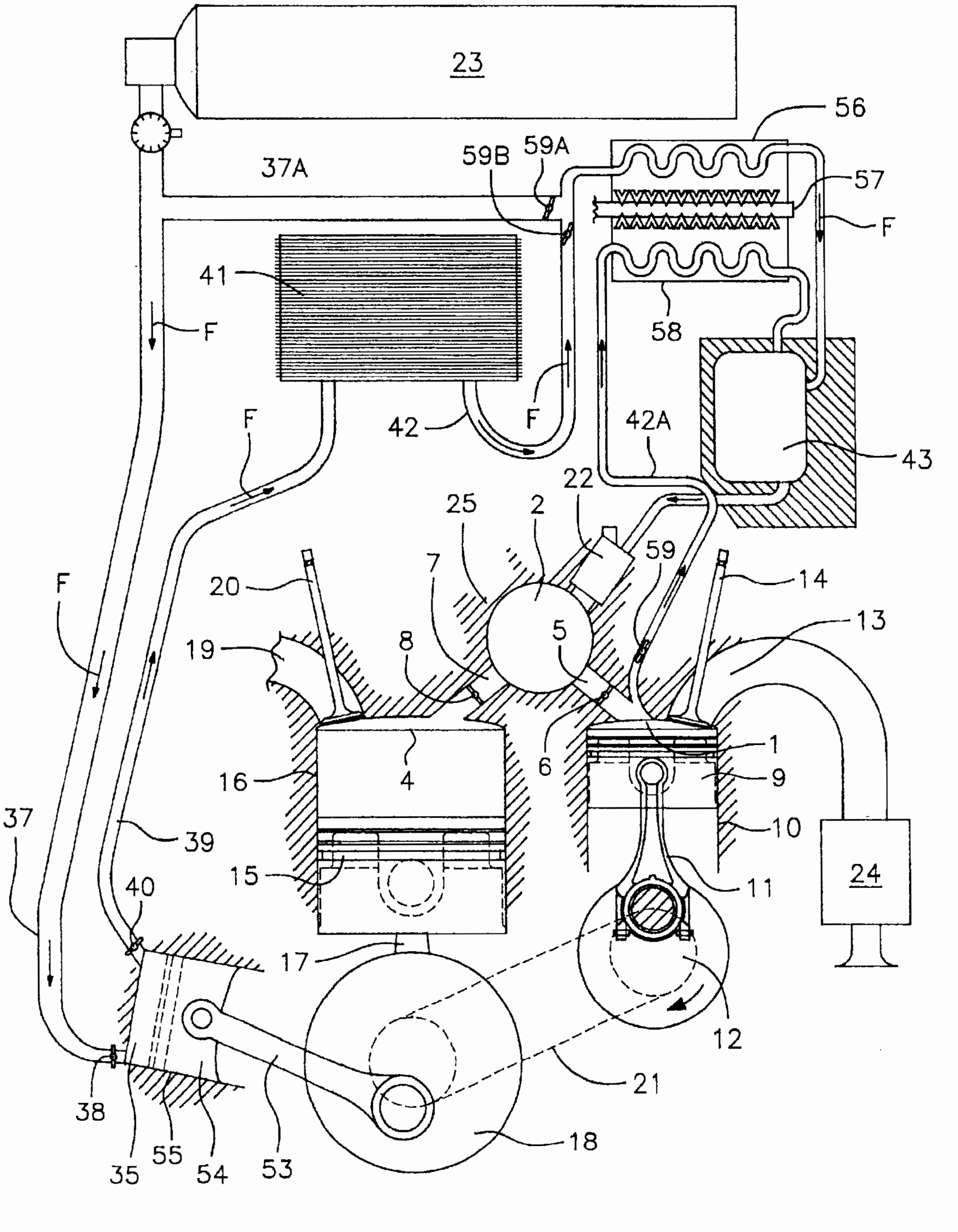
FIG. 4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METHOD AND DEVICE FOR ADDITIONAL THERMAL HEATING FOR MOTOR VEHICLE EQUIPPED WITH POLLUTION-FREE ENGINE WITH ADDITIONAL COMPRESSED AIR INJECTION

The invention relates to land vehicles and more particularly to those equipped with engines that are free of pollution or that reduce pollution with independent or otherwise combustion chambers operating with the injection of additional compressed air and comprising a high-pressure compressed-air reservoir.

In his published patent application WO 96/27737, the author has described a depolluting method for an engine with an independent external combustion chamber, operating on a two-mode principle using two types of energy, using either conventional fuel such as gasoline or diesel oil on the highway (single-mode air/fuel operation) or, at low speed, particularly in urban and suburban areas, using an addition of compressed air (or any other non-polluting gas) into the combustion chamber to the exclusion of any other fuel (single-mode air operation, that is to say operation with the addition of compressed air). In his patent application FR 96/07714, the author has described the installation of this type of engine in single-mode operation, with the addition of compressed air, on service vehicles, for example town buses.

In this type of engine, in air/fuel mode, the air/fuel mixture is taken into and compressed in an independent intake and compression chamber. This mixture is then transferred, still at pressure, into a constant-volume independent combustion chamber where it is ignited to increase the temperature and pressure of said mixture. Once a transfer port connecting said combustion or expansion chamber with an expansion and exhaust chamber has opened, this mixture will be expanded in the latter chamber where it will produce work. The expanded gases are then discharged to the atmosphere through an exhaust pipe.

When operating on air plus additional compressed air, this being the mode of most interest in the context of the invention, at low power, the fuel injector is no longer operated; in this case, a small amount of additional compressed air from an external reservoir in which the air is stored at high pressure, for example 200 bar, and at ambient temperature is introduced into the combustion chamber appreciably after the (fuel-free) compressed air from the intake and compression chamber has been let into this chamber. This small amount of compressed air at ambient temperature heats up upon contact with the mass of air at high temperature contained in the combustion or expansion chamber, expands and increases the pressure prevailing in the chamber so as to allow motive power to be delivered during expansion.

This type of dual-mode or dual-energy (air and fuel or air and additional compressed air) engine can also be modified for a preferred use in town, for example, on all vehicles and more particularly on town buses or other service vehicles (taxis, garbage trucks, etc.), in air/additional compressed air single-mode operation by dispensing with all the elements whereby the engine operates with the conventional fuel.

The engine operates only in single mode with the injection of additional compressed air into the combustion chamber, which thus becomes an expansion chamber. Furthermore, the air taken in by the engine can be filtered and purified through one or more charcoal filters or using some other mechanical or chemical method or molecular sieve or some other filter so as to produce a pollution-reducing engine. In the current text, the use of the term "air" should be understood as meaning "any non-polluting gas".

In this type of engine, the additional compressed air is injected into the combustion or expansion chamber at a service pressure that is determined according to the pressure prevailing in the chamber and appreciably higher than this pressure, so as to allow its transfer, for example 30 bar. To do this, use is made of a pressure-reducing expander of conventional type, which performs work-free expansion without absorbing heat, and therefore without lowering the temperature, thus allowing expanded air (at about 30 bar in our example) and at ambient temperature to be injected into the combustion or expansion chamber.

This method of injecting additional compressed air can also be used on conventional two- or four-stroke engines in which said injection of additional compressed air into the combustion chamber of the engine is performed approximately at top dead center on an ignition stroke.

The method according to the invention proposes a solution which makes it possible to increase the amount of energy available and which can be used. It is characterized by the means employed and more specifically by the fact that the compressed air, before being introduced into the combustion and/or expansion chamber, is routed through a thermal heater where its pressure and/or volume increases, thus considerably improving the performance that can be achieved by the engine.

In his patent application No. 9700851, the author has also described a method for recovering heat energy from the surroundings for this type of engine in which the compressed air contained in the storage reservoir at very high pressure, for example 200 bar, and at ambient temperature, for example 20°, prior to its end use at a lower pressure of, for example, 30 bar is expanded to a pressure close to the pressure needed for its end use in a variable-volume system, for example in a piston in a cylinder, producing work which can be recovered and used by any known means, mechanical, electrical, hydraulic or the like. This expansion with work has the consequence of cooling the compressed air which has been expanded to a pressure close to the service pressure to a very low temperature, for example −100° C. This compressed air, expanded to its service pressure, and at very low temperature is then sent into an exchanger with the ambient air, is heated up to a temperature close to ambient temperature, and its pressure and/or its volume thus increases, recovering the thermal energy taken from the atmosphere.

Another feature of the method according to the invention proposes a solution which involves the method for recovering heat energy which has just been described hereinabove and which makes it possible to further improve the amount of energy available and that can be used. It is characterized by the means implemented and more particularly by the fact that the compressed air, having passed through the air/air heat exchanger and before being introduced into the combustion chamber, is routed into a thermal heater where it once again increases in pressure and/or in volume before being introduced into the combustion and/or expansion chamber, but considerably improving the performance that can be achieved by the engine.

The use of a thermal heater has the advantage that it is possible to use clean continuous combustion which can be catalyzed or cleaned by any known means, it can be supplied with a conventional fuel such as gasoline, diesel oil, butane gas, propane gas, LPG or the like, just as it may use chemical reactions and/or electrical energy to produce the heating of the compressed air passing through it.

The person skilled in the art will be able to calculate the amount of very-high-pressure air to be supplied to the expansion-with-work system, and the characteristics and volumes of the latter so as, at the end of this expansion with work, and bearing in mind the heating power, to obtain the chosen final service pressure and the temperature which is as cold as possible, and to do so according to the use of the engine. Electronic management of parameters makes it possible at every instant to optimize the amounts of compressed air used, recovered and heated. The person skilled in the art will also be able to determine the engineering details and characteristics of the thermal heater which can employ any concept known in this field without altering the method of the invention.

According to one feature of the invention, the thermal heater used to heat the compressed air from the high-pressure storage reservoir, which may or may not come via the system for recovering heat energy from the ambient surroundings, is also used, independently or in combination with the two solutions described hereinabove, that is to say directly from the storage reservoir or via the heat energy recuperator, to heat up compressed air taken from the engine intake and compression chamber, thus increasing its pressure and/or its volume before re-introducing it into the combustion and/or expansion chamber to allow an increase in the pressure of the gases contained in said combustion chamber prior to expansion in the expansion and exhaust cylinder which produces the power stroke.

The compressed air sent into the thermal heater comes from the storage reservoir, from the device for recovering heat energy from the ambient surroundings, from a tapping from the intake and compression chamber, separately or in combination, in proportions that are determined according to the conditions of use.

Other objects, advantages and features of the invention will become apparent upon reading the nonlimiting description of a number of particular embodiments which are given with reference to the appended drawings in which:

FIG. 1 is a diagrammatic depiction in cross section of a pollution-free engine equipped with a thermal heater device,

FIG. 2 is a depiction, in cross section, of a pollution-free engine with recovery of heat energy from the ambient surroundings, equipped with a thermal heater device,

FIG. 3 is a depiction of an engine equipped with a thermal heater device as a bypass on the compressed air through the intake-compression chamber,

FIG. 4 is a depiction of an engine combining all three solutions.

FIG. 1 is a diagrammatic depiction in cross section of a pollution-free engine and of its compressed-air supply installation, comprising an intake and compression chamber **1**, a constant-volume combustion or expansion chamber **2** in which there is an additional air injector **22** supplied with compressed air stored in a very-high-pressure reservoir **23** and an expansion and exhaust chamber **4**. The intake and compression chamber **1** is connected to the combustion or expansion chamber **2** by a pipe **5**, the opening and closure of which are controlled by a sealed shutter **6**. The combustion or expansion chamber **2** is connected to the expansion and exhaust chamber **4** by a pipe or transfer port **7**, the opening and closure of which are controlled by a sealed shutter **8**. The intake and compression chamber **1** is supplied with air by an intake pipe **13**, the opening of which is controlled by a valve **14** and upstream of which there is a pollution-reducing charcoal filter **24**.

The intake and compression chamber **1** operates like a piston compressor assembly in which a piston **9**, sliding in a cylinder **10**, is controlled by a connecting rod **11** and a crankshaft **12**. The expansion and exhaust chamber **4** controls a conventional piston-engine assembly with a piston **15** sliding in a cylinder **16**, which, via a connecting rod **17**, drives the rotation of a crankshaft **18**. The expanded air is exhausted through an exhaust pipe **19**, the opening of which is controlled by a valve **20**. The rotation of the crankshaft **12** of the intake and compression chamber **1** is controlled through a mechanical link **21** by the drive crankshaft **18** of the expansion and exhaust chamber **4**.

According to the invention, fitted on the pipe **37A** between the high-pressure storage reservoir **23** and a buffer volume at the almost constant end-usage pressure **43**, is a thermal heater **56** consisting of burners **57** which considerably increase the temperature and therefore the pressure and/or the volume of the compressed air from the reservoir **23** (in the direction of the arrows F) as it passes through the exchange coil **58** to allow a considerable improvement in engine performance.

The engine is equipped in FIG. 2 with a device for recovering heat energy from the ambient surroundings, in which the expansion with work of the high-pressure compressed air stored in the reservoir **23** is performed in an assembly comprising connecting rod **53** and working piston **54** coupled directly to the drive shaft **18**. This piston **54** slides in a blind cylinder **55** and determines a working chamber **35** into which there open, on the one hand, a high-pressure air intake pipe **37**, the opening and closure of which are controlled by an electrically operated valve **38** and, on the other hand, an exhaust pipe **39** connected to the air/air heat exchanger or radiator **41** which is itself connected by a pipe **42** to a buffer volume **43** at the practically constant end-usage pressure. During operation, when the working piston **54** is at its top dead center, the electrically operated valve **38** is opened then closed again so as to let in a charge of very-high-pressure compressed air which will expand, driving back the piston **54** as far as its bottom dead center, and drive the engine crankshaft **18** via the connecting rod **53**. During the upstroke of the piston **54**, the electrically operated exhaust valve **40** is then opened and compressed but expanded and very-low-temperature air contained in the working chamber is discharged (in the direction of the arrow F) into the air/air heat exchanger or radiator **41**. This air will thus be heated up to a temperature close to ambient temperature and will increase in volume as it reaches the buffer volume **43** having recuperated a not insignificant amount of energy from the atmosphere.

According to the invention, fitted between the air/air exchanger **41** and the buffer volume **43** on the pipe **42A** is a thermal heater **56** consisting of burners **57** which will considerably increase the temperature and therefore the pressure and/or the volume of the compressed air coming (in the direction of the arrows F) from the air/air exchanger **41** as it passes through the exchange coil **58**.

According to one feature of the invention, in FIG. **3**, the thermal heater **56** is fitted as a bypass of the intake and compression chamber **1**, from which some of the air compressed by the piston **9** is directed (in the direction of the arrows F) toward the thermal heater **56** and as it passes through the exchange coil **58** heated by the burners **57** it will increase in pressure and/or in volume before being introduced into the buffer volume **43** and being injected by the injector **22** into the combustion and/or expansion chamber **2**.

FIG. **4** depicts a diagrammatic view of a device combining the three devices described in FIGS. **1** and **2** and **3**, the burners **57** of the thermal heater **56** at the same time heating up some of the air compressed by the piston **9** of the intake and compression chamber **1** in an exchange coil **58** before driving it into the buffer volume **43** and the compressed air from the storage reservoir via the device for recovering heat energy from the ambient surroundings and the air/air exchanger **41**.

The thermal heater **56** receives compressed air from the storage reservoir **23** along a pipe **37A**, from the device **41** for recovering thermal energy from the ambient surroundings along another pipe **42** and from the intake and compression chamber **1** along a third pipe **42A**; each of these pipes has a controlled regulating valve **59**, **59A**, **59B** which makes it possible to determine the proportions of compressed air from each source that are to be heated according to the conditions of use.

Systems of regulating valves, for igniting the burners and for regulating the intensity of the burners are installed for heating to a greater or lesser extent the compressed air which passes through the heating coil according to the energy requirements for the driving of the vehicle thus equipped.

The buffer volume **43** placed between the thermal heater **56** and the injector **22** may advantageously be lagged by an insulating jacket **43A**, made of materials known for this purpose, to make it possible for the compressed air to retain the heat energy accumulated in the thermal heater **56** before being injected into the chamber. The person skilled in the art will be able to choose the size of the buffer volume **43** and the lagging materials and similarly the pipework and various pipes may also be lagged without this in any way altering the invention which has just been described.

Of course, the invention is not restricted to the embodiments described and depicted and can be varied in numerous ways accessible to those skilled in the art without in any way departing from the spirit of the invention.

What is claimed is:

1. In a thermal heating method for an engine or vehicle equipped with an engine that is free of pollution or that reduces pollution, operating with injection of additional air into a combustion or expansion chamber and which has a high-pressure compressed-air storage reservoir, the improvement which comprises:

expanding compressed air contained in the high-pressure storage reservoir, prior to its final use at a lower pressure and prior to being introduced into a thermal heater to allow at least one of its pressure and its volume to increase before it is injected into the combustion or expansion chamber, to a pressure in a variable-volume system, producing work, the consequence of which is that of cooling the compressed air thus expanded to a low temperature,

thereafter sending the thus-cooled air into a heat exchanger to heat it and thus increase at least one of its pressure and its volume by recovering additional heat energy from ambient surroundings.

2. A method according to claim **1** wherein the variable-volume system is a piston in a cylinder.

3. A thermal heating method according to claim **1**, wherein the compressed air which is sent into the thermal heater comes from the storage reservoir, from a device for recovering heat energy from ambient surroundings, from a tapping from an intake and compression chamber separately or in combination, in proportions that are determined according to conditions of use.

4. A thermal heating method according to claim **1**, wherein the compressed air which is sent into the thermal heater comes from the storage reservoir, from the device for recovering heat energy from ambient surroundings, from a tapping from the intake and compression chamber separately or in combination, in proportions that are determined according to conditions of use.

5. A thermal heater device which comprises a thermal heater (**56**), a burner (**57**), a heat-exchange coil (**58**), a storage reservoir (**23**), an additional compressed air injector (**22**), a combustion or expansion chamber (**2**), and a buffer volume (**43**), wherein the thermal heater (**56**), which consists of the burner (**57**) fed with a fuel and of the heat-exchange coil (**58**), is positioned between the storage reservoir (**23**) and the additional compressed air injector (**22**), the burner (**57**) being means for heating up the air from the storage reservoir as it passes through the coil (**58**) so as to increase at least one of its pressure and its volume before it is injected into the combustion or expansion chamber (**2**), the buffer volume (**43**) being positioned between the thermal heater and the additional compressed air injector (**22**) making it possible to even out and avoid surge effects prior to said injection.

6. A thermal heater device according to claim **5** further comprising a pipe (**42**) and a radiator (**41**), wherein the thermal heater (**56**) is positioned on the pipe (**42**) between the air/air heat exchanger or radiator (**41**) of the device for recovering heat energy from the ambient surroundings and the buffer volume (**43**) before it is injected into the combustion of expansion chamber (**2**).

7. A thermal heater device according to claim **5** further comprising a heat exchanger (**56**), an intake and compression chamber (**1**), a pipe (**42**) and a valve (**59**), wherein the heat exchanger (**56**) is positioned between the intake and compression chamber (**1**) of the engine and the buffer volume (**43**) on a bypass circuit consisting of the pipe (**42**) in which flow rate is controlled by the valve (**59**) which allows compressed air at the end of compression to be tapped off to be directed to the thermal heater so that at least one of its pressure and its volume can be increased before it is injected into the combustion or expansion chamber.

8. A thermal heater device according to claim **5** further comprising one pipe (**37A**), a device (**41**) for recovering heat energy from the ambient surroundings, a second pipe (**42**), an intake and compression chamber (**1**), a third pipe (**42A**), and a controlled regulating valve (**59**, **59A**, **59B**), wherein the thermal heater (**56**) receives compressed air from the storage reservoir (**23**) along the one pipe (**37A**), from the device (**41**) for recovering heat energy from the ambient surroundings along the second pipe (**42**), and from the intake and compression chamber (**1**) along the third pipe (**42A**), and wherein each of these pipes comprises the controlled regulating valve (**59**, **59A**, **59B**) that makes it possible to determine the proportions of compressed air from each source that is to be heated according to the conditions of use.

9. A thermal heater device according to claim **5**, which further comprises a jacket (**43A**) and wherein the buffer volume placed between the thermal heater (**56**) and the injector (**22**) is lagged by the jacket (**43A**) to allow the heat energy accumulated in the thermal heater to be retained.

10. A thermal heating method for an engine or vehicle equipped with an engine that is free of pollution or that reduces pollution, operating with the injection of additional air into the combustion or expansion chamber, wherein compressed air is taken from the intake and compression chamber at the end of compression to be directed toward a thermal heater so that at least one of its pressure and its volume can be increased before it is injected into the combustion or expansion chamber.

11. A thermal heating method according to claim **10**, wherein the compressed air which is sent into the thermal heater comes from the storage reservoir, from the device for recovering heat energy from the ambient surroundings, from a tapping from the intake and compression chamber separately or in combination, in proportions that are determined according to conditions of use.

* * * * *

US006311486B1

(12) **United States Patent**
Negre et al.

(10) **Patent No.: US 6,311,486 B1**
(45) **Date of Patent: Nov. 6, 2001**

(54) **METHOD FOR OPERATING A POLLUTION-REDUCING ENGINE**

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(73) Assignee: **Guy Negre**, Brignoles (FR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/202,608**

(22) PCT Filed: **Jun. 17, 1997**

(86) PCT No.: **PCT/FR97/01088**

§ 371 Date: **Sep. 1, 1999**

§ 102(e) Date: **Sep. 1, 1999**

(87) PCT Pub. No.: **WO97/48884**

PCT Pub. Date: **Dec. 24, 1997**

(30) **Foreign Application Priority Data**

Jun. 17, 1996 (FR) 96 07714

(51) **Int. Cl.**^{7} **F01B 29/10**
(52) **U.S. Cl.** **60/370**; 60/412
(58) **Field of Search** 60/39.6, 39.62, 60/370, 407, 409, 410, 412, 414, 415, 417, 419, 712; 123/22; 180/302

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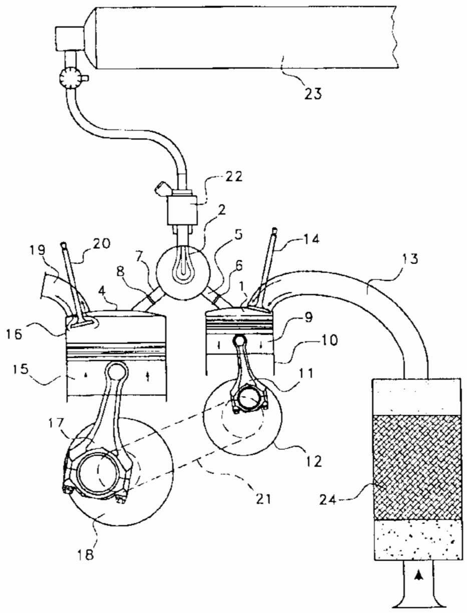
(74) *Attorney, Agent, or Firm*—Duane Morris LLP

(57) **ABSTRACT**

A method for reducing pollution in a mono-mode air-air combustion engine having an intake and compression chamber, connected to a constant volume expansion chamber, which is connected in turn to an expansion and exhaust chamber. External air is drawn into the intake chamber and compressed to an increased pressure and temperature. The compressed air is transferred to the constant volume expansion chamber, wherein additional, ambient temperature, compressed air is injected therein. The injected air, when contacting the elevated pressure and temperature of the compressed air causes an expansion of the air within the constant volume expansion chamber. The energy associated with the air expansion is transferred to the expansion and exhaust chamber, wherein the continued compressed air expansion produces a work force that is imparted to a piston. The energy depleted air is then exhausted through an exhaust value.

16 Claims, 1 Drawing Sheet



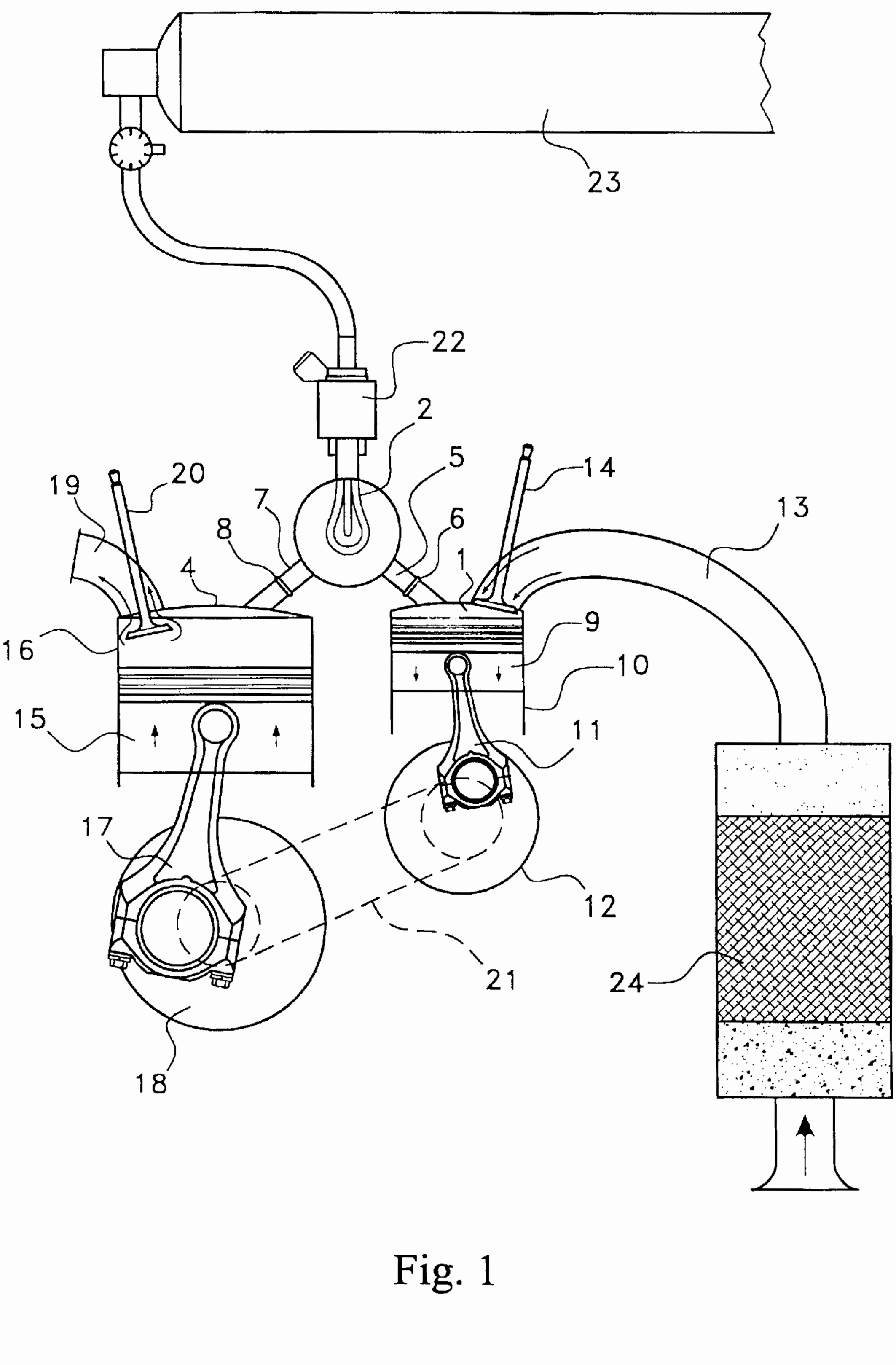


Fig. 1

METHOD FOR OPERATING A POLLUTION-REDUCING ENGINE

FIELD OF THE INVENTION

The invention relates to internal combustion engine. More specifically, a method for a pollution-reducing engine with an independent expansion chamber.

BACKGROUND OF THE INVENTION

In urban and suburban areas, public transport is very often provided by urban buses propelled by conventional engines, which are usually diesel engines that employ a heterogeneous mixture, e.g., diesel fuel, which are particularly polluting. Attempts at making these vehicles run on fuels said to be less polluting (LPG, etc.) have been made, but the results in terms of pollution are particularly weak.

A method for reducing pollution of an engine with an independent external combustion chamber, has described, in the inventor's French patent application, recorded under national record number 95/02838, in which method, the air-fuel mixture is drawn into and compressed in an independent intake and compression chamber then transferred (still under pressure) into the independent combustion chamber to be ignited therein, either using a spark in the case of an engine with a homogenous mixture, or by self-ignition in the case of a diesel engine with a heterogeneous mixture, in order to increase the temperature and pressure of the said mixture which, following the opening of a transfer connecting the said independent combustion chamber to an expansion and exhaust chamber (it too independent), will be expanded in the latter chamber in order to produce work therein, then exhausted to the atmosphere through an exhaust pipe, in which method, when operating in town (or at low power), the fuel injector is no longer operated and, in this case, there is introduced into the combustion chamber, somewhat after the fuel-free compressed air from the intake and compression chamber has been let into the latter, a small amount of additional compressed air from an external reservoir where the compressed air is stored at very high pressure. This small amount of compressed air at ambient temperature will heat up upon contact with the mass of hot air contained in the combustion chamber, and will expand so as to increase the pressure in the combustion chamber to allow work to be delivered during expansion. This engine thus employs a dual-mode or dual-energy operation.

There is a need for an engine, especially for the urban markets, that use less fuel and aid in reducing the pollution caused by other vehicles using conventional internal combustion engines.

SUMMARY OF THE INVENTION

The method of a pollution-reducing engine and its installation in urban buses, for example, makes it possible to eliminate emissions of polluting gases but also allows pollution to be removed partially and considerably from the air in the town.

It is characterized by the means employed, and more particularly by the elimination of the fuel circuit of the engine in favor of simply having mono-mode operation with the injection of additional compressed air, and by fitting upstream of the air intake into the intake an compression chamber of the engine, one or more charcoal filters or any other filtering and purification method, such as molecular sieves, chemical methods or the like, not only allowing dust and other pollutants to be halted, but also allowing the air let into the engine to be purified and pollution removed therefrom.

The additional compressed air stored at very high pressure in the reservoirs of the vehicle is filtered and purified through charcoal filters or the like before being compressed, the ambient air (polluted by the other vehicle) drawn in by the engine into the intake and compression chamber is filtered and purified through the charcoal filter or filters (or any other method that allows it the be purified): it is therefore clear that the air expanded and exhausted through the exhaust is still filtered and purified. Furthermore, as the mode of running the engine on traditional fuel has been eliminated, there can no longer remain in the chamber any particles or other residue originating from a prior combustion.

Other objects, advantages and features of the invention will become clear from reading the non-limiting description of one embodiment of the invention, this being given with reference to the appended drawing.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 depicts, diagrammatically, and in cross section, one embodiment of the engine according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, there is shown intake and compression chamber **1**, the constant-volume expansion chamber **2** in which there is fitted an injector **22** for additional compressed air, this injector being fed with compressed air stored in a very high pressure reservoir **23** and the expansion and exhaust chamber **4**. The intake and compression chamber **1** connected to the expansion chamber **2** by a port **5**, the opening and closing of which are controlled by a leaktight shutter **6**. The expansion chamber **2** is connected to the expansion and exhaust chamber **4** by a port or transfer **7** the opening and closing of which is controlled by a leaktight shutter **8**.

The intake and compression chamber **1** is fed with air via an intake port **13**, the opening of which is controlled by a valve **14**, and upstream of which is installed a pollution-removing charcoal filter **24**. The intake and compression chamber **1** operates like a reciprocating-compressor unit in which a piston **9** sliding in a cylinder **10** is controlled by a connecting rod **11** and a crankshaft **12**. The expansion and exhaust chamber **4** controls a conventional piston-engine unit with a piston **15** sliding a cylinder **16** which, via a connecting rod **17**, rotates a crankshaft **18**. The expanded air is exhausted through an exhaust port **19**, the opening of which is controlled by a valve **20**. The rotation of the crankshaft **12** of the intake and compression chamber **1** is brought about, through a mechanical link **21**, by the motive-power crankshaft **18** of the expansion and exhaust chamber **4**. The engine is depicted at a time when the air which has been purified and had pollution removed from it through the charcoal filter **24** has been drawn into compressed in the expansion chamber **2** during the induction-compression cycle performed by the piston/connecting-rod/crank unit (**9**,**10**,**11**) and the port **5** has been closed by the leaktight shutter **6**. The air, from which pollution has been removed, which has been purified and which has been compressed in the expansion chamber **2** is therefore at a high temperature (several hundred degrees depending on the compression ratios chosen) and the injector **22** of additional compressed air is then operated and lets in a small amount of compressed air at ambient temperature which is expanded to a pressure somewhat higher than the pressure in the expansion chamber **2** so as to allow it to enter the chamber; this small amount of compressed air will heat up on contact with the high-temperature mass of air contained in the expansion chamber, will expand and increase the pressure so as to produce work as it expands, this expansion being brought about when the piston of the expansion chamber **15** reaches top dead center, by opening the transfer duct **7** controlled by the leaktight shutter **8**. Expansion occurs with hot air until the expansion piston **15** that drives the motor-power crankshaft **18** reaches bottom dead center, and the expanded, pollution-free and purified air is then exhausted to the atmosphere through the exhaust pipe **19** the value **20** being open while the piston **15** of the expansion and exhaust chamber **4** is on its up-stroke.

The methods used to filter the air let into the engine according to the invention, e.g., charcoal filters, molecular sieves, micrometric sieves, chemical methods, etc., and the number of filters used can vary without altering the principles of the invention, just as a unit made up of an intake and compression chamber, a combustion chamber, and an expansion and exhaust chamber, which represents an operating element, can be duplicated following the example of conventional multi-cylinder engines.

The engine method according to the invention can be applied to all vehicles, but it requires a large amount of additional compressed air and relatively large storage reservoirs on board the vehicle. It is particularly attractive when installed on urban buses on account, on the one hand, of the large amount of air drawn in by the engine, which therefore allows pollution to be removed from substantial volumes and, on the other hand, of the possibility of installing large-capacity reservoirs of additional compressed air on the bus and because, incidentally, as buses make numerous stops, it is possible for the reservoir or reservoirs of additional compressed air installed on the vehicle to be refilled more often by installing filling stations at the bus stops or at the depot. The same is true of service vehicles such as taxis or small vans operating in an urban environment.

What is claimed is:

1. A method for operating an air-air mono-mode pollution reducing engine comprising an independent intake and compression chamber which is connected via a transfer to a constant volume expansion chamber connected to an expansion and exhaust chamber, said expansion and exhaust chamber hang an exhaust port contained therein, and a reservoir for air at a very high pressure and an injector connected to said constant volume expansion chamber, said intake and compression chamber and said expansion and exhaust chamber having a piston therein connected to a respective crankshaft and a linkage between said crankshafts, said method comprising the steps of:

drawing air into said intake and compression chamber;

compressing said air drawn into said intake and compression chamber to an increased pressure and temperature;

transferring said compressed air having increased pressure and temperature to said constant volume expansion chamber;

injecting additional air at ambient temperature from said reservoir into said constant volume expansion chamber with said compressed air;

opening the transfer leading from said constant volume expansion chamber to said expansion and exhaust chamber thus producing work within said expansion and exhaust chamber by allowing said compressed air and injected air to expand into said expansion and exhaust chamber; and

exhausting said compressed and injected air out of said engine; wherein, no fuel is introduced into said engine.

2. The method of claim **1**, wherein said additional air injected into said constant volume expansion chamber is injected at ambient temperature.

3. The method of claim **1**, wherein said drawn air is filtered prior to entering said intake and compression chamber.

4. The method of claim **1**, wherein said step of compressing is dependent upon said physical work produced.

5. The method of claim **1**, further comprising the step of recharging said reservoir.

6. A method for operating an engine comprising an intake and compression chamber, a constant volume expansion chamber coupled to said intake and compression chamber, an expansion and exhaust chamber coupled to said constant volume expansion chamber, and a reservoir coupled to said constant volume expansion chamber, said intake and compression chamber and said expansion and exhaust chamber having a piston therein connected to a respective crankshaft and a linkage between said crankshafts, said method comprising the step of:

drawing air into said intake and compression chamber;

compressing said air drawn into said intake and compression chamber thus raising it to an elevated pressure and temperature;

transferring said compressed air into said constant volume expansion chamber at said elevated pressure and temperature;

injecting additional air into said constant volume expansion chamber from said reservoir, thus further increasing said elevated temperature and pressure of said compressed air;

allowing said compressed air to expand in said expansion and exhaust chamber thus performing physical work; and

exhausting said compressed and injected air out of said engine, wherein, no fuel is supplied to said engine.

7. The method of claim **6**, wherein said additional air injected into said constant volume expansion chamber is injected at ambient temperature.

8. The method of claim **6**, wherein said drawn air is filtered prior to entering said intake and compression chamber.

9. The method of claim **6**, wherein said step of compressing is dependent upon said physical work produced.

10. The method of claim **6**, further comprising the step of recharging said reservoir.

11. A method for operating an air-fuel/air-air dual-mode dual-energy reducing engine without using fuel, the dual-mode dual-energy engine comprising an independent intake and compression chamber connected via a transfer to an expansion and exhaust chamber, an exhaust port, a reservoir for high pressure air and an air injector, said intake and compression chamber and said expansion and exhaust chamber having a piston therein connected to a respective crankshaft and a linkage between said crankshafts, said method comprising the steps of:

drawing air into said intake and compression chamber;

compressing said air drawn into said intake and compression chamber thus raising it to an elevated pressure and temperature;

tansferring said compressed air into a constant volume expansion chamber at said elevated pressure and temperature;

injecting additional air into said constant volume expansion chamber from said reservoir, thus further increasof compressed air will heat up on contact with the high-temperature mass of air contained in the expansion chamber, will expand and increase the pressure so as to produce work as it expands, this expansion being brought about when the piston of the expansion chamber **15** reaches top dead center, by opening the transfer duct **7** controlled by the leaktight shutter **8**. Expansion occurs with hot air until the expansion piston **15** that drives the motor-power crankshaft **18** reaches bottom dead center, and the expanded, pollution-free and purified air is then exhausted to the atmosphere through the exhaust pipe **19** the value **20** being open while the piston **15** of the expansion and exhaust chamber **4** is on its up-stroke.

The methods used to filter the air let into the engine according to the invention, e.g., charcoal filters, molecular sieves, micrometric sieves, chemical methods, etc., and the number of filters used can vary without altering the principles of the invention, just as a unit made up of an intake and compression chamber, a combustion chamber, and an expansion and exhaust chamber, which represents an operating element, can be duplicated following the example of conventional multi-cylinder engines.

The engine method according to the invention can be applied to all vehicles, but it requires a large amount of additional compressed air and relatively large storage reservoirs on board the vehicle. It is particularly attractive when installed on urban buses on account, on the one hand, of the large amount of air drawn in by the engine, which therefore allows pollution to be removed from substantial volumes and, on the other hand, of the possibility of installing large-capacity reservoirs of additional compressed air on the bus and because, incidentally, as buses make numerous stops, it is possible for the reservoir or reservoirs of additional compressed air installed on the vehicle to be refilled more often by installing filling stations at the bus stops or at the depot. The same is true of service vehicles such as taxis or small vans operating in an urban environment.

What is claimed is:

1. A method for operating an air-air mono-mode pollution reducing engine comprising an independent intake and compression chamber which is connected via a transfer to a constant volume expansion chamber connected to an expansion and exhaust chamber, said expansion and exhaust chamber hang an exhaust port contained therein, and a reservoir for air at a very high pressure and an injector connected to said constant volume expansion chamber, said intake and compression chamber and said expansion and exhaust chamber having a piston therein connected to a respective crankshaft and a linkage between said crankshafts, said method comprising the steps of:

drawing air into said intake and compression chamber;

compressing said air drawn into said intake and compression chamber to an increased pressure and temperature;

transferring said compressed air having increased pressure and temperature to said constant volume expansion chamber;

injecting additional air at ambient temperature from said reservoir into said constant volume expansion chamber with said compressed air;

opening the transfer leading from said constant volume expansion chamber to said expansion and exhaust chamber thus producing work within said expansion and exhaust chamber by allowing said compressed air and injected air to expand into said expansion and exhaust chamber; and

exhausting said compressed and injected air out of said engine; wherein, no fuel is introduced into said engine.

2. The method of claim **1**, wherein said additional air injected into said constant volume expansion chamber is injected at ambient temperature.

3. The method of claim **1**, wherein said drawn air is filtered prior to entering said intake and compression chamber.

4. The method of claim **1**, wherein said step of compressing is dependent upon said physical work produced.

5. The method of claim **1**, further comprising the step of recharging said reservoir.

6. A method for operating an engine comprising an intake and compression chamber, a constant volume expansion chamber coupled to said intake and compression chamber, an expansion and exhaust chamber coupled to said constant volume expansion chamber, and a reservoir coupled to said constant volume expansion chamber, said intake and compression chamber and said expansion and exhaust chamber having a piston therein connected to a respective crankshaft and a linkage between said crankshafts, said method comprising the step of:

drawing air into said intake and compression chamber;

compressing said air drawn into said intake and compression chamber thus raising it to an elevated pressure and temperature;

transferring said compressed air into said constant volume expansion chamber at said elevated pressure and temperature;

injecting additional air into said constant volume expansion chamber from said reservoir, thus further increasing said elevated temperature and pressure of said compressed air;

allowing said compressed air to expand in said expansion and exhaust chamber thus performing physical work; and

exhausting said compressed and injected air out of said engine, wherein, no fuel is supplied to said engine.

7. The method of claim **6**, wherein said additional air injected into said constant volume expansion chamber is injected at ambient temperature.

8. The method of claim **6**, wherein said drawn air is filtered prior to entering said intake and compression chamber.

9. The method of claim **6**, wherein said step of compressing is dependent upon said physical work produced.

10. The method of claim **6**, further comprising the step of recharging said reservoir.

11. A method for operating an air-fuel/air-air dual-mode dual-energy reducing engine without using fuel, the dual-mode dual-energy engine comprising an independent intake and compression chamber connected via a transfer to an expansion and exhaust chamber, an exhaust port, a reservoir for high pressure air and an air injector, said intake and compression chamber and said expansion and exhaust chamber having a piston therein connected to a respective crankshaft and a linkage between said crankshafts, said method comprising the steps of:

drawing air into said intake and compression chamber;

compressing said air drawn into said intake and compression chamber thus raising it to an elevated pressure and temperature;

tansferring said compressed air into a constant volume expansion chamber at said elevated pressure and temperature;

injecting additional air into said constant volume expansion chamber from said reservoir, thus further increasing said elevated temperature and pressure of said compressed air;

allowing said compressed air to expand in said expansion and exhaust chamber thus performing physical work; and

exhausting said compressed and injected air out of said engine; wherein no fuel is supplied to said engine.

12. The method of claim **11**, wherein said additional air injected into said constant volume expansion chamber is injected at ambient temperature.

13. The method of claim **11**, wherein said drawn air is filtered prior to entering said intake and compression chamber.

14. The method of claim **11**, wherein said step of compressing is dependent upon said physical work produced.

15. The method of claim **11**, further comprising the step of recharging said reservoir.

16. The method of claim **11**, wherein said compressed air and said injected air are fuel-free.

* * * * *

US006327858B1

(12) **United States Patent**
Negre et al.

(10) **Patent No.: US 6,327,858 B1**
(45) **Date of Patent: Dec. 11, 2001**

(54) AUXILIARY POWER UNIT USING COMPRESSED AIR

(76) Inventors: **Guy Negre**; **Cyril Negre**, both of 4c ave. BP 547, Carros Cedex (FR), F-06516

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/744,236**

(22) PCT Filed: **Jul. 27, 1999**

(86) PCT No.: **PCT/FR99/01834**

§ 371 Date: **Jan. 25, 2001**

§ 102(e) Date: **Jan. 25, 2001**

(87) PCT Pub. No.: **WO00/07278**

PCT Pub. Date: **Feb. 10, 2000**

(30) **Foreign Application Priority Data**

Jul. 27, 1998 (FR) 98 09799

(51) **Int. Cl.**^{7} **F01K 25/02**
(52) **U.S. Cl.** **60/650**; 60/659
(58) **Field of Search** 60/643, 650, 659

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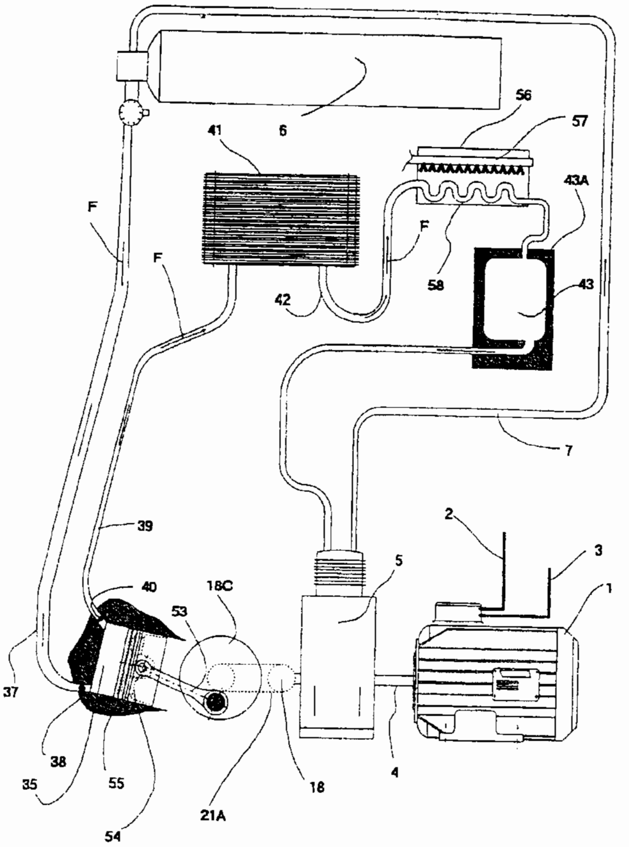
Primary Examiner—Hoang Nguyen
(74) *Attorney, Agent, or Firm*—Jacobson Holman, PLLC

(57) ABSTRACT

The invention concerns an auxiliary power unit using compressed air for energy and equipped with a motor alternator driving, or being driven by a motor compressor with compressed air which compresses air under high pressure in a high pressure storage tank and which when there is a power cut automatically drives the motor compressor in alternating mode to supply electricity. The invention is applicable to fixed or mobile auxiliary power units.

12 Claims, 1 Drawing Sheet



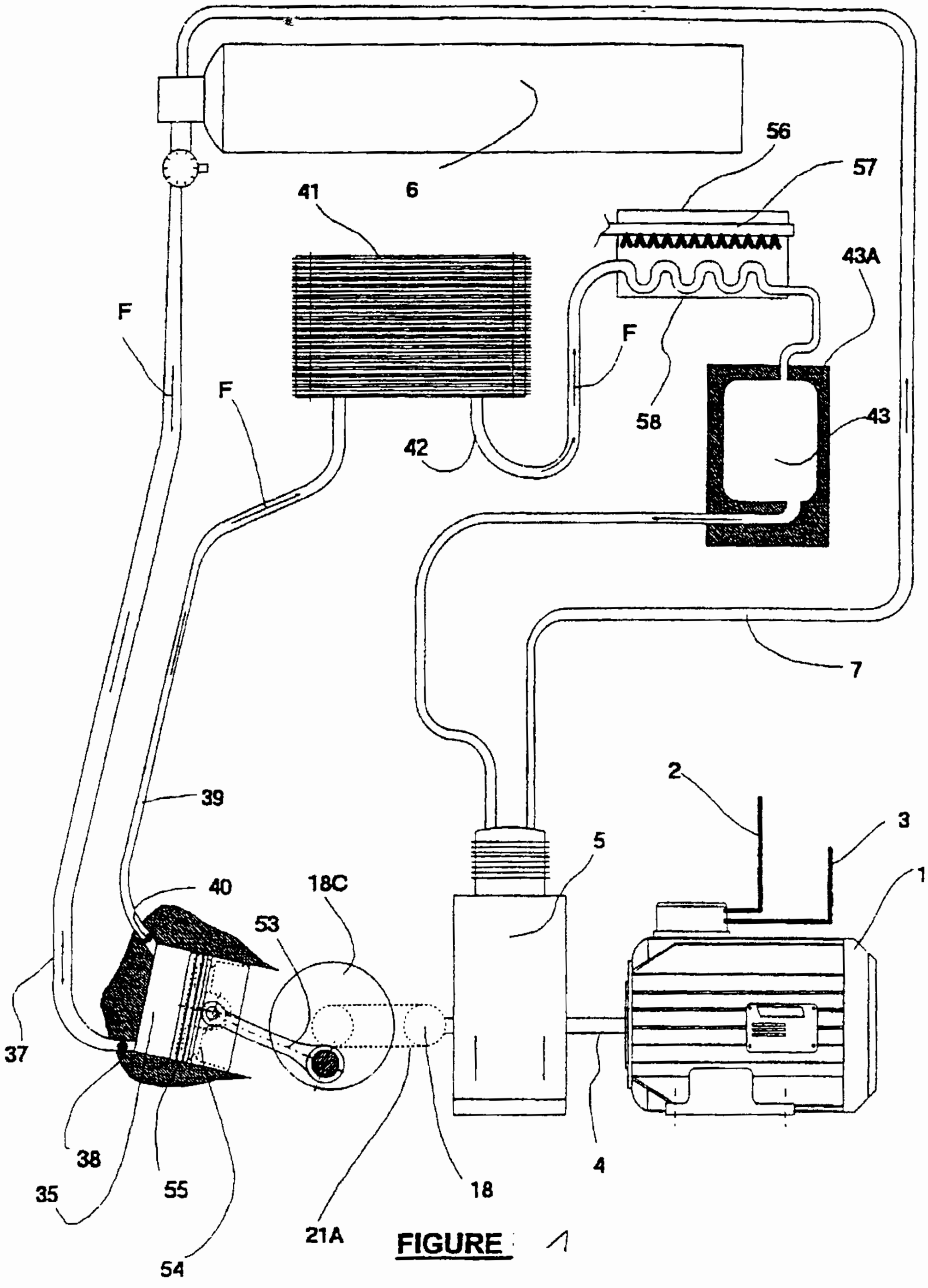


FIGURE 1

AUXILIARY POWER UNIT USING COMPRESSED AIR

The invention relates to a back-up generator set operating on compressed air.

Current generator sets mainly comprise an alternator tasked with producing electricity while they are running, driven by a combustion engine running on petrol, diesel or some other gas. These engines are particularly noisy and polluting and consume expensive energy which has frequently to be replenished. Systems allowing the use of compressed air as a reserve of energy have been described, in particular, in patent U.S. Pat. No. 5,296,799, but use complex solutions involving numerous parts with an air compressor, a compressed-air motor, an alternator and an electric motor.

The author has filed numerous published patent applications, WO 96/27737, WO 97/48884, WO 98/12062, WO 98/15440, regarding the use of compressed air as energy storage, particularly for driving vehicle engines or for other uses.

The generator set according to the invention sets out to solve the problems associated with supplying generator sets with fuel, by using compressed air to operate it; it comprises a reversible compressed-air motor which can operate either as a motor or as a compressor—compressed-air motor-compressor—driven by, or driving an electric motor which is also reversible and which can operate as a generator—motor-generator. During operation, the motor-generator, in electric motor mode, which receives its power from an electricity network, for example the town mains, runs, driving the compressed-air motor-compressor which is therefore in compressor mode and fills one or more high-pressure, for example 200 bar, compressed-air reservoirs and keeps them full. When there is a break in the electricity supply, for example during a power cut, the motor-compressor is automatically switched into motor mode and, powered with energy by the compressed air contained in the storage reservoir or reservoirs, it drives the motor-generator which has also been automatically switched into generator mode to supply electricity.

The switch from one mode of operation to the other is managed by an electromechanical, electronic or some other device.

As a preference, the back-up generator set according to the invention comprises a system for recuperating ambient thermal energy as described by the author in his patent application No. FR 97/00851, where the compressed air contained in the storage reservoir at very high pressure, for example 200 bar, and at ambient temperature, for example 20 degrees C., prior to its end use in the motor-compressor, at a pressure below 30 bar for example, has its pressure reduced to a pressure close to that needed for its end use, in a variable-volume system, for example a piston in a cylinder, producing work which can be recuperated and used by any known means, mechanical, electrical, hydraulic or other. This pressure reduction with work has the result of cooling the compressed air which has had its pressure reduced to a pressure close to the service pressure to a very low temperature, for example minus 100° C. This pressure-reduced compressed air at its service pressure and at a very low temperature is then sent into an exchanger with the ambient air, is reheated to a temperature close to ambient temperature, and thus increases its pressure and/or its volume, recuperating the heat energy taken from the atmosphere.

As another preference, the engine operating method according to the invention comprises a thermal heating system as described by the author in his patent application FR 98/00877, in which he proposes a solution which allows the amount of usable and available energy to be increased, characterized by the fact that the compressed air, before being let into the engine combustion and/or expansion chamber, coming from the storage reservoir either directly or after passing through the air-air heat exchanger and before being let into the combustion chamber is routed through a heater in which its pressure and/or volume increases still further before it is let into the combustion and/or expansion chamber, thus considerably improving performance still further.

When the back-up generator set is used in buildings supplied with town gas, the heater may advantageously be supplied with the said town gas.

The back-up generator set according to the invention may be installed in a set location in buildings or other private dwellings. It may also be fitted to a mobile unit which will be powered with electricity and have its reservoirs filled before being used on outdoor sites.

Other objects, advantages and features of the invention will emerge from reading the description, with no implied limitation, of several embodiments, which is given with reference to the appended drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

The single FIGURE represents a block diagram of the operation of the generator in this invention.

DETAIL DESCRIPTION OF THE DRAWINGS

The single FIGURE represents a block diagram of the operation of the generator set according to the invention, in which the electric motor-generator **1** powered from the electricity network by an electric cable **2** or powering the electricity network by an electric cable **3** driving, or being driven through a transmission **4** by the motor-compressor **5** which in compressor mode fills a high-pressure storage reservoir **6** via a pipe **7** and which in compressed-air motor mode receives from the storage reservoir **6** compressed air which has already had its pressure reduced, with work, in a variable-volume device allowing a considerable reduction in the temperature of the air whose pressure is reduced to a pressure approximately equivalent to the working pressure of the motor-compressor the pressure reduction with work of the high-pressure compressed air stored in the reservoir **6** is performed in an assembly comprising connecting rod **53** and working piston **54**, coupled directly to a crankshaft **18C** connected to the motor crankshaft **18** by a transmission **21A**. This piston **54** slides in a blind cylinder **55** and determines a working chamber **35** into which there open, on the one hand, a high-pressure air intake pipe **37**, the opening and closure of which are controlled by an electrically operated valve **38** and, on the other hand, an exhaust pipe **39** connected to an air-air heat exchanger or radiator **41** itself connected by a pipe **42** to a buffer volume **43** at almost constant end-use pressure, itself equipped with thermal insulation **43A**. During operation when the working piston **54** is at its top dead center, the electrically operated valve **38** is opened then closed again to admit a charge of very high pressure compressed air which will expand, driving the piston **54** back to its bottom dead center, producing work, and via the connecting rod **53** drive the crankshaft **18C** and via the transmission **21A** drive the crankshaft of the motor-compressor **18**. During the upstroke of the piston **54**, the exhaust electrically operated valve **40** is then opened and the compressed air whose pressure has been practically reduced to the service pressure and at very low temperature contained in the working chamber is discharged (in the direction of the arrow F) into the air-air exchanger or radiator **41**. This air will thus be heated up to a temperature close to ambient temperature and will increase in volume as it reaches the buffer volume **43**, having recuperated a not-insignificant amount of energy from the atmosphere.

Between the air-air exchanger **41** and the buffer volume **43**, on the pipe **42**, there is also a heater **56**, consisting of burners **57** which will considerably increase the temperature and therefore the pressure and/or the volume of the compressed air from (in the direction of the arrows F) the air-air exchanger **41** as it passes through the exchange coil **58**.

The modes of switching, the types of motor-generator and motor-compressor, the design of the storage reservoirs and their volume may of course employ known or unknown methods without in any way changing the principle of the invention which has just been described.

What is claimed is:

1. Back-up generator set operating on reserves of compressed air, characterized in that the compressed-air motor is reversible and operates either in compressed-air motor mode or in compressed-air compressor mode—compressed-air motor-compressor (5)—driven by, or driving, an electric motor which is also reversible which can act as a generator—motor-generator (1)—in which, during operation, the motor-generator in electric motor mode which receives its energy from an electricity network, runs, driving the compressed-air motor-compressor, operating in compressor mode, which fills one or more high-pressure compressed-air reservoirs and keeps them full and in which, when there is a break in the electrical power supply, the motor-compressor is automatically switched to motor mode and powered with energy by the compressed air contained in the storage reservoir or reservoirs (6) and drives the motor-generator which has also automatically been switched into generator mode to provide back-up electrical power.

2. Back-up generator set according to claim 1, characterized in that, prior to being let into the motor-compressor, the compressed air contained in the high-pressure storage reservoir (6) has its pressure reduced with work producing a drop in its temperature and is then sent to an exchanger (41) with ambient air to be heated up again and thus have its pressure and/or its volume increased, recovering ambient thermal energy.

3. Back-up generator set according to claim 1 characterized in that, prior to being let into the motor-compressor, the compressed air from the storage reservoir is routed, either directly or after it has passed through the air-air heat exchanger, through a thermal heater (**56**) to further increase its pressure and/or its volume.

4. Back-up generator set according to claim **3**, characterized in that the energy used for the thermal heater is town gas.

5. Back-up generator set according to claim **1**, characterized in that the entire generator set with its storage reservoir and its accessories is mounted on a mobile body which allows it to be used on an outdoor site.

6. Back-up generator set according to claim **2**, characterized in that, prior to being let into the motor-compressor, the compressed air from the storage reservoir is routed, either directly or after it has passed through the air-air heat exchanger, through a thermal heater (**56**) to further increase its pressure and/or its volume.

7. Back-up generator set according to claim **6**, characterized in that the energy used for the thermal heater is town gas.

8. Back-up generator set according to claim **2**, characterized in that the entire generator set with its storage reservoir and its accessories is mounted on a mobile body which allows it to be used on an outdoor site.

9. Back-up generator set according to claim **3**, characterized in that the entire generator set with its storage reservoir and its accessories is mounted on a mobile body which allows it to be used on an outdoor site.

10. Back-up generator set according to claim **4**, characterized in that the entire generator set with its storage reservoir and its accessories is mounted on a mobile body which allows it to be used on an outdoor site.

11. Back-up generator set according to claim **6**, characterized in that the entire generator set with its storage reservoir and its accessories is mounted on a mobile body which allows it to be used on an outdoor site.

12. Back-up generator set according to claim **7**, characterized in that the entire generator set with its storage reservoir and its accessories is mounted on a mobile body which allows it to be used on an outdoor site.

* * * * *

US006334435B1

(12) **United States Patent**
Negre et al.

(10) **Patent No.: US 6,334,435 B1**
(45) **Date of Patent: Jan. 1, 2002**

(54) METHOD FOR OPERATING POLLUTION-FREE ENGINE EXPANSION CHAMBER AND EXPANSION CHAMBER THEREFOR

(76) Inventors: **Guy Negre**; **Cyril Negre**, both of BP 547 Carros Cedex, Carros (FR), F-06516

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/720,245**

(22) PCT Filed: **Jul. 9, 1998**

(86) PCT No.: **PCT/FR98/01483**

§ 371 Date: **Jan. 4, 2001**

§ 102(e) Date: **Jan. 4, 2001**

(87) PCT Pub. No.: **WO00/03123**

PCT Pub. Date: **Jan. 20, 2000**

(51) **Int. Cl.**^{7} **F02B 33/00**

(52) **U.S. Cl.** **123/559.1**; 60/597

(58) **Field of Search** 123/559.1; 60/605, 60/606, 597, 599

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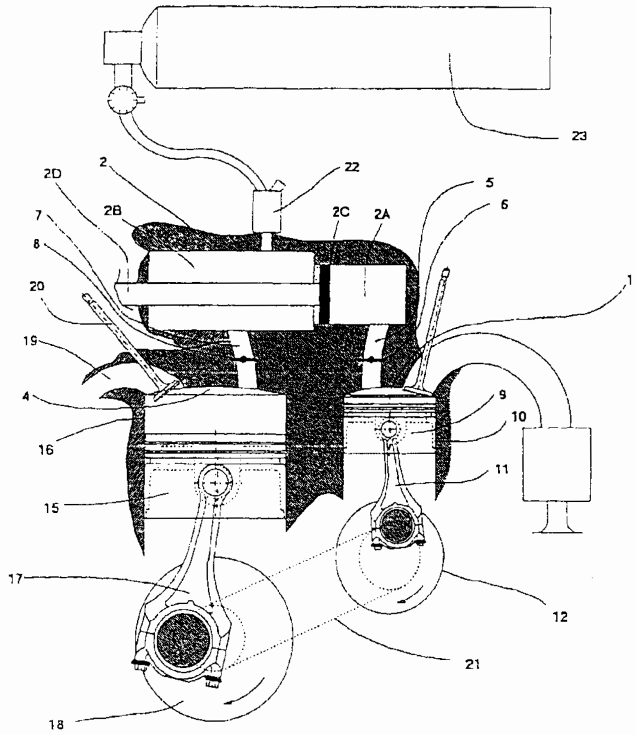
(74) *Attorney, Agent, or Firm*—Jacobson Holman, PLLC

(57) ABSTRACT

The invention concerns a method for operating a pollution-free engine chamber by injecting supplementary compressed air, comprising a suction and compression chamber (**1**) and an expansion and exhaust chamber (**4**) independent of each other, which consists in separating the pressure increase process in said expansion chamber by dividing it into the two chambers, an engine chamber (**2A**) which receives high pressure air and a working chamber (**2B**) which receives the supplementary compressed air with lower pressure, separated by a quick-operating plug (**2***c*) which communicates them suddenly thereby causing, owing to difference in pressure levels, a wave expanding the engine gas which flows into the working chamber generating a compressive shock wave substantially increasing the pressure level in the chamber shortly before it is communicated with the expansion and exhaust cylinder (**4**) to produce a work.

6 Claims, 3 Drawing Sheets



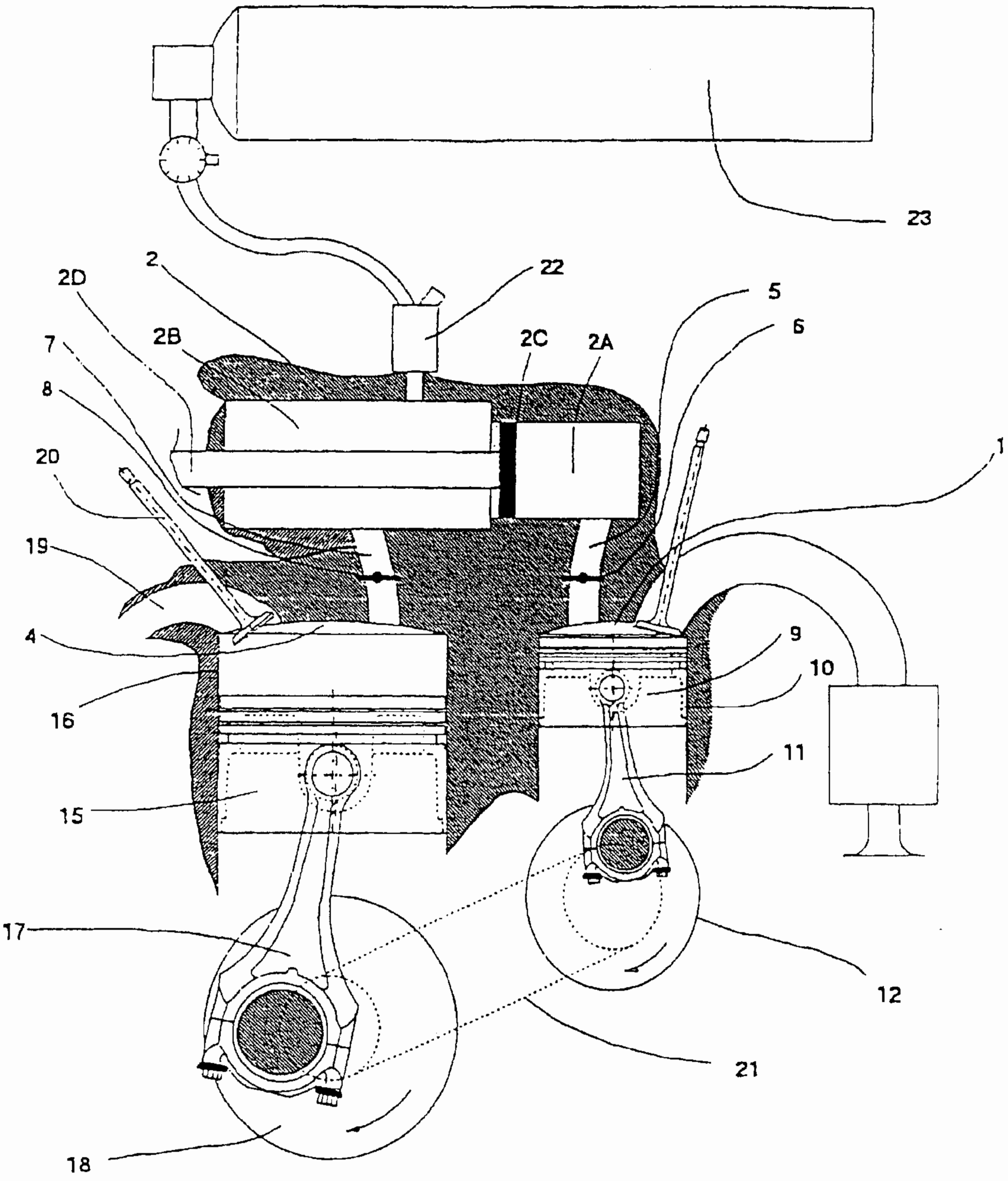


FIG. 1

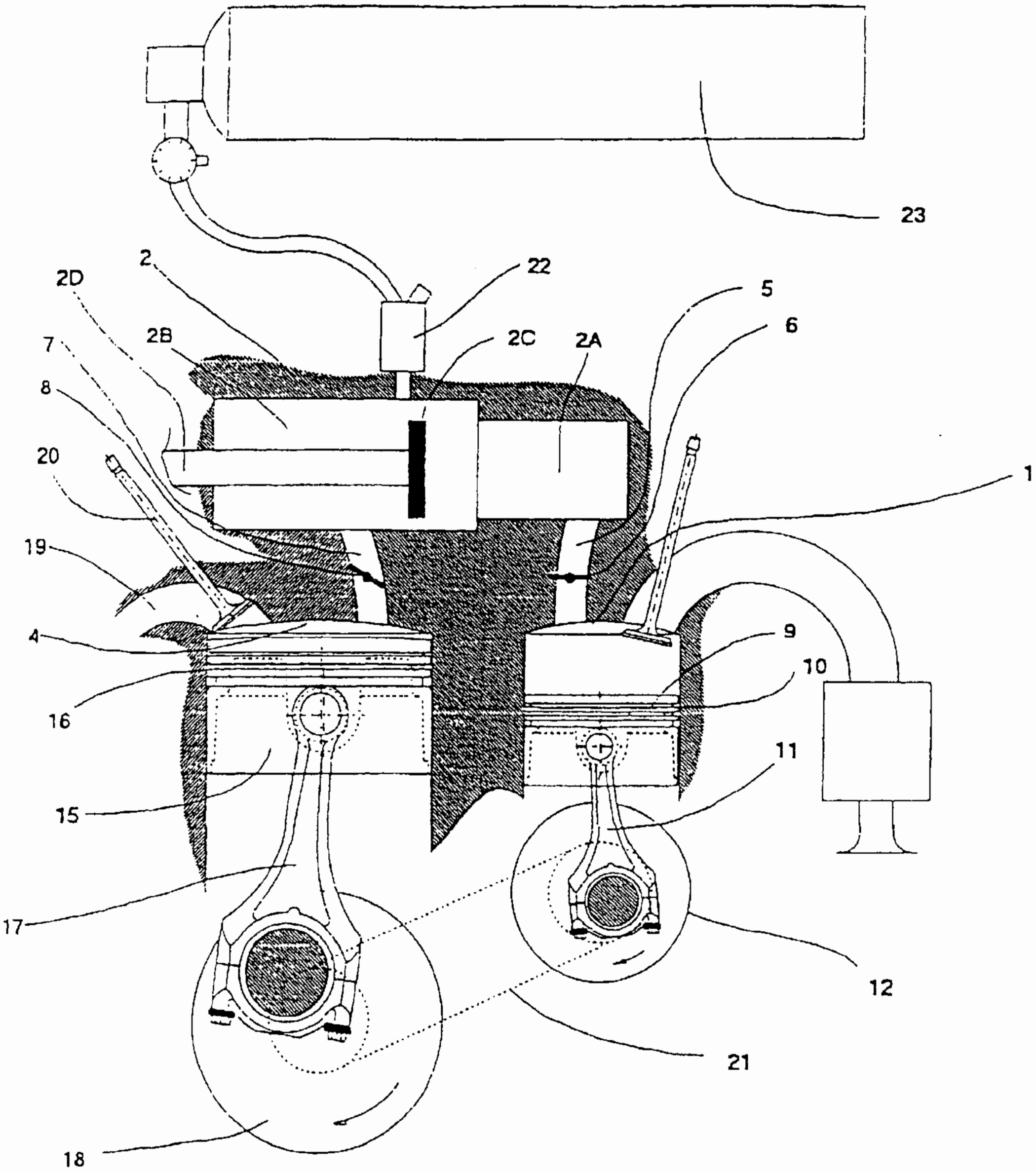


FIG. 2

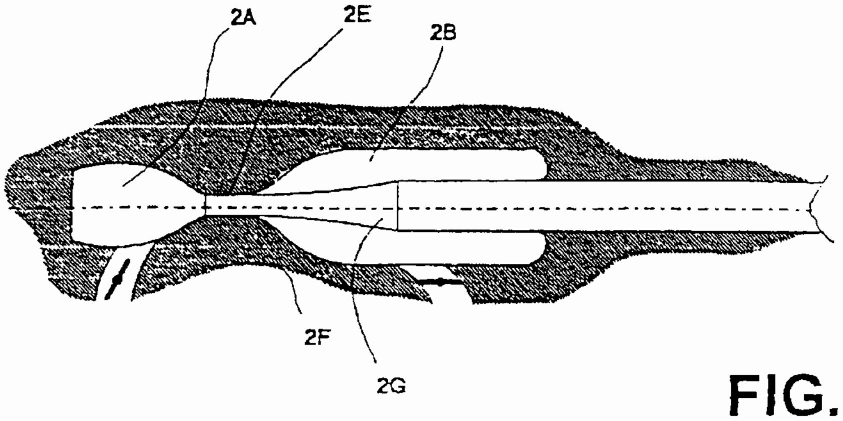


FIG. 3

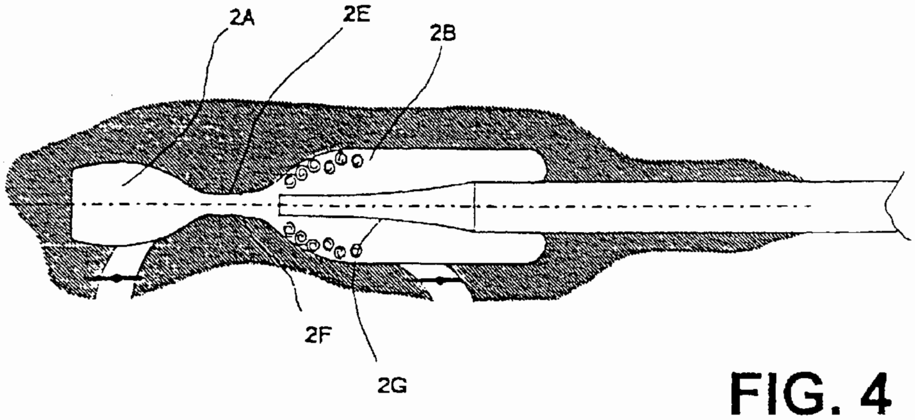


FIG. 4

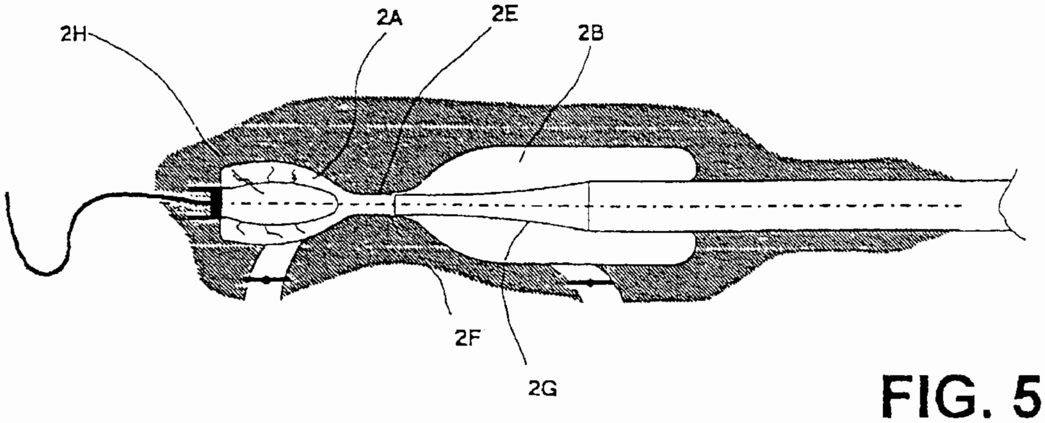


FIG. 5

METHOD FOR OPERATING POLLUTION-FREE ENGINE EXPANSION CHAMBER AND EXPANSION CHAMBER THEREFOR

The invention relates to the operation of an expansion chamber of a pollution-free or depolluting engine with injection of additional compressed air.

In his published patent application WO 96/27737, the author has described a method for reducing pollution of an engine with an independent external combustion chamber operating on a dual-mode principle with two types of energy, using either conventional fuel of the gasoline or diesel oil type on the highway (in single-mode air-fuel operation) or, at low speed, particularly in towns and suburbs, with an addition of compressed air (or any other non-polluting gas) to the exclusion of any other fuel (so-called single-mode air-air operation, that is to say with the addition of compressed air). In his patent application WO 97/48884, the author has described the installing of this type of engine in single-mode operation on service vehicles, for example town buses, taxis or delivery vans.

In air-fuel mode, the air-fuel mixture is drawn into and compressed in an independent induction and compression chamber. This mixture is then transferred, still under pressure, to an independent and constant-volume combustion chamber where it is ignited in order to increase the temperature and pressure of the said mixture. Once a transfer port connecting the said combustion or expansion chamber to an expansion and exhaust chamber has opened, this mixture will be expanded in the latter chamber to produce work there. The expanded gases are then discharged to the atmosphere through an exhaust pipe.

When operating in air-air mode, at low power, the fuel injector is no longer operated; in this case, a small amount of additional compressed air from an external tank in which the air (or any other gas) is stored at high pressure, for example 200 bar, and at ambient temperature is introduced into the combustion chamber somewhat after the (fuel-free) compressed air from the induction and compression chamber has been let into this combustion chamber. Upon the injection of additional compressed air, this small amount of compressed air at ambient temperature will heat up in contact with the mass of high-temperature air contained in the combustion or expansion chamber, will expand and will increase the pressure obtaining in the chamber to allow work to be delivered upon expansion.

This type of dual-mode or dual-energy (air and gasoline or air and additional compressed air) engine can also be modified for preferential use, in town for example, on all vehicles and particularly on town buses or other service vehicles (taxis, trash-collecting trucks, etc.) in air-compressed air single mode by eliminating all the elements of the engine which operate in conjunction with the conventional fuel.

The engine then runs only in single mode with the injection of additional compressed air into the combustion chamber which thus becomes an expansion chamber. Furthermore, the air drawn in by the engine can be filtered or purified through one or more charcoal filters or using some other method—mechanical, chemical, molecular sieve, or other filters in order to produce a depolluting engine. The use of the term "air" in the current text is to be understood as meaning "any non-polluting gas".

In this type of engine, the additional compressed air is injected into the combustion or expansion chamber at a service pressure determined according to the pressure obtaining in the chamber and appreciably higher than this pressure. This entails relatively high injection pressures, for example of 30 bar.

The problems of the dynamics of the gases in fluid flows have been extensively studied and tested. In supersonic flows, the pressure waves emitted by the moving bodies form envelopes of shapes on the passage of which the air undergoes so-called very high-speed variations and physical properties which result in particular in the appearance of shock waves. Tests and experiments performed with a shock tube have been intended to carry out numerous experiments in the area of dynamics of gases and to determine their properties and in the area of supersonic wind tunnels (shock tunnels). A shock tube consists of two tube parts where a diaphragm is clamped between two ends and where the free ends are closed. One of the parts is known as the driving tube and the other part is known as the test tube and the entire entity is known as the shock tube. By filling the test tube with the gas on which tests are to be performed and by compressing the gas in the driving tube until the diaphragm bursts, a process of pressure equalization then ensues. The high-pressure driving gas expands in the form of an expansion wave and flows into the test tube. It therefore creates a shock wave in the low-pressure gas.

The method of operation of the expansion chamber according to the invention proposes the use of shock and shock wave techniques in subsonic and more particularly supersonic gaseous flows in order to get the best possible output from the engine by obtaining high pressures and temperatures of the gases in the expansion chamber before the said gas is transferred into the expansion and exhaust chamber. It consists in splitting the process of increasing the pressure in the chamber into two stages, by introducing a high-pressure driving gas from the induction and compression chamber into part of the said chamber and, on the other hand, by introducing the additional compressed air into the other part at a markedly lower pressure, then in suddenly bringing the two parts into contact to obtain, because of the pressure difference, a sudden expansion of the driving gas which expands in the form of an expansion wave and flows into the working gas at lower pressure, thereby creating a compression shock wave which makes it possible to considerably increase the total pressure in the chamber shortly before it expands in the expansion and exhaust chamber to produce work.

As a preference, the method of operation of the expansion chamber according to the invention involves ionization of the driving gas before it is introduced into the working chamber, which has the effect of creating waves of electromagnetic nature and of increasing the intensity of the shock wave in the working chamber and of delaying the relaxation phenomena.

The expansion chamber for the implementation of the method is divided into two parts separated by a very high-speed shutter which can bring them suddenly into communication at the chosen moment in the cycle; one of these chambers, known as the driving chamber, is connected to the induction and compression chamber and receives the driving gas therefrom; the second chamber is connected to the expansion and exhaust chamber and receives the additional compressed air; it thus becomes the working chamber. The operation of the expansion chamber according to the invention can thus be understood; first of all, the driving chamber is filled with hot compressed air at high pressure, for example 50 bar, from the induction and compression chamber, while an amount of additional compressed air from a storage tank under high pressure is injected so as to obtain a lower pressure, for example 10 bar, in the working chamber then, shortly before communication with the engine expansion cylinder, the inter-chamber shutter is suddenly opened; as a result, and because of the pressure difference, the driving gas will expand in the form of an expansion wave and will flow into the working chamber where it creates a compression shock wave and considerably increases the pressure in the said working chamber shortly before it is placed in communication with the expansion and exhaust cylinder. This increase in pressure is used to produce the work by expanding the gases in the expansion and exhaust chamber.

According to another feature of the invention, the shapes of the two chambers are in the form of nozzles where the driving chamber opens via a convergent section into a throat closed by a high-speed shutter which allows it to be opened suddenly at the chosen moment in the cycle, and onto the working chamber via a divergent section such that the supersonic jet created when the throat is opened causes the formation of vortexes, which, aside from the shock wave effects, make it possible to produce the desired pressure-increasing effects.

It is possible to calculate and choose the volumes of the driving chamber and of the working chamber, to optimize the shapes and sizes, to create one or more shocks triggering waves and/or vortexes without altering the method of the invention.

It is also possible, within the cycle, to choose the moment that the inter-chamber shutter opens and that the transfer into the expansion chamber occurs, so as to obtain the desired results, namely the highest possible pressure in the expansion chamber at the time of the expansion.

Other objects, advantages and features of the invention will become apparent from reading the non-limiting description of a number of embodiments given by reference to the appended drawings where:

FIG. **1** depicts a view in cross section of an entire engine equipped with the expansion chamber according to the invention;

FIG. **2** depicts this same engine shortly before expansion;

FIG. **3** depicts, in cross section, an expansion chamber in the form of a nozzle;

FIG. **4** depicts this same chamber with its shutter open;

FIG. **5** depicts an expansion chamber according to the invention, the driving chamber of which is fitted with a cathode.

FIG. **1**, in which the various items are not to scale in order to give a better understanding of the diagrammatically depicted drawing, and viewed in cross section, is one embodiment of an entire engine equipped with the expansion chamber according to the invention. The induction and compression chamber and the expansion and exhaust chamber are each controlled by a connecting rod-crank system and pistons sliding in the cylinders, and it is possible to see the induction chamber and the compression chamber **1**, the expansion chamber **2** divided into two parts, the driving chamber **2A** and the working chamber **2B**, separated by a shutter **2C**, and its control **2D**. An additional-air injector **22**, supplied with compressed air stored in a very high pressure tank **23**, is installed in the working chamber **2B**. The induction and compression chamber **1** is connected to the driving chamber **2A** of the expansion chamber **2** by a duct **5**, the opening and closure of which are controlled by a sealed flap **6**. The working chamber **2B** of the expansion chamber **2** is connected to the expansion and exhaust chamber **4** by a duct or transfer port **7**, the opening and closure of which are controlled by a sealed flap **8**. The induction and compression chamber **1** operates as a piston compressor unit where the piston **9** sliding in a cylinder **10** is controlled by a connecting rod **11** and a crankshaft **12**. The expansion and exhaust chamber **4** controls a conventional engine piston unit with a piston **15** sliding in a cylinder **16** which, via a connecting rod **17**, drives the rotation of a crankshaft **18**; expanded air is exhausted through an exhaust pipe **19**, the opening of which is controlled by a valve **20**. The rotation of the crankshaft **12** of the induction and compression chamber **1** is controlled through a mechanism **21** by the engine crankshaft **18** of the expansion and exhaust chamber **4**. It goes without saying that the two connecting rods may also be coupled to the same crankshaft, but the solution drawn is more demonstrative of the independence of the chambers. The engine is depicted at compressor top dead center, the sealed flap **6** is closed and the driving chamber **2A** of the expansion chamber **2** is filled with air compressed to high pressure by the piston **9**, the additional-air injector **22** is or has just been actuated to obtain in the working chamber **2B** compressed air at a pressure lower than that obtaining in the driving chamber **2A**, the high-speed shutter **2C** is then actuated to suddenly place the driving chamber **2A** and the working chamber **2B** in communication (FIG. **2**). Because of the pressure difference, the driving gas will expand in the form of an expansion wave and propagate through the working chamber where it creates a compression shock wave causing a considerable increase in pressure in the working chamber **2B**; before the relaxation phenomenon causes this pressure to decay to the pressure that the mixing of the gases contained in the two chambers would produce, and as the piston **15** of the expansion chamber reaches its top dead center, the opening of the passage **7** is brought about by the flap **8**, to allow the gases contained in the working chamber to expand until the expansion piston **15** reaches bottom dead center, driving the engine crankshaft **18** and producing work.

FIG. **3** depicts a view in longitudinal section of another embodiment of the expansion chamber according to the invention, where the general outline of the chamber is in the form of a nozzle making it possible, during operation, to generate the formation of toroidal vortexes. The driving chamber **2A** is connected to the working chamber **2B** by a throat **2E** in which a sliding piston **2G** provides the mutual separation. In the inlet throat just before the divergent there is a flat increase in section **2F** accompanied by a return intended, upon opening by the piston, to create the shock wave and encourage the creation of vortexes depicted symbolically in FIG. **4**. The driving chamber **2A** containing the driving gas at high pressure converges towards the inlet throat **2E**, the diameter of which is chosen according to the desired Mach number, opening onto the diverging walls of the working chamber **2B**. A piston-shutter rod **2G** separates the two chambers and forms a central core which will cause annular flow. Upon operation and at the chosen moment in the engine cycle, the shutter piston **2F** retires and suddenly places the two chambers in communication when its head uncovers the flat increase in section **2F**. Because of the pressure difference, the gas contained in the driving chamber **2A** expands into the working chamber **2B**, creating a compression shock wave therein. The presence of the shutter piston **2G** causes the flow to separate and encourages the creation of vortexes.

FIG. **5** depicts an expansion chamber according to the invention, similar to the one described in FIGS. **3** and **4**, where a cathode **2H** intended to ionize the gas has been introduced into the driving chamber **2A** with a view to creating waves of electromagnetic nature, to increasing the intensity of the shock wave and to delaying the relaxation phenomena.

Of course, the invention is not in any way restricted to the embodiments described and depicted; several entities such as those described may be grouped together and produced in the manner of multicylinder engines, the shapes and sizes may vary and it can be modified in numerous ways accessible to those skilled in the art, according to the envisaged applications, without departing from the spirit of the invention as defined by the claims.

What is claimed is:

1. Method of operation of an engine comprising an expansion chamber, an induction and compression chamber (**1**) and an expansion and exhaust chamber (**4**) which are independent, with the injection of an additional compressed non-polluting gas into the expansion chamber (**2**) in which a process of pressure increase occurs, characterized in that it consists in splitting the process of increasing the pressure in the expansion chamber into two stages, by introducing, on the one hand, a high-pressure driving gas from the induction and compression chamber into part of the expansion chamber and by introducing non-polluting so-called "working gas" on the other hand, the additional compressed into the other part of the expansion chamber at a pressure markedly lower than the pressure obtaining in the first part, then in suddenly bringing the two parts into contact to obtain, because of the pressure difference, a sudden expansion of the driving gas which expands in the form of an expansion wave and flows into the working gas, thereby creating a compression shock wave which makes it possible to considerably increase the total pressure in the expansion chamber shortly before it expands in the expansion and exhaust chamber to produce work.

2. Method of operation of an expansion chamber according to claim **1**, characterized in that the shape of the expansion chamber is tailored to the creation of vortexes which amplify the effects of the compression shock wave.

3. Method of operation of an expansion chamber according to claim **1**, characterized by ionization of the driving gas which ionization creates electromagnetic waves to increase the intensity of the shock wave and delay the onset of relaxation phenomena.

4. Engine with the injection of an additional compressed non-polluting gas for implementing the method of claim **1**, consisting of an induction and compression chamber (**1**), of an expansion and exhaust chamber (**4**) and of an expansion chamber (**2**) which are separate, in which engine a small amount of additional compressed non-polluting gas from an external tank (**23**) in which the gas is stored under very high pressure is introduced into the expansion chamber (**2**), characterized in that the expansion chamber (**2**) is divided into two parts (2A, 2B) separated by a very high-speed shutter (2C) which brings them suddenly into communication at the chosen moment in the cycle, one of these parts, known as the "driving chamber" (2A), is connected to the induction and compression chamber (**1**) and receives the high-pressure driving gas therefrom, the second part, the so-called "working chamber" (2B), is connected to the expansion and exhaust chamber (**4**) and receives the additional compressed non-polluting gas, a compression shock wave developing when the inter-chamber shutter (2C) is suddenly opened as a result of the pressure difference, causing a significant increase in pressure shortly before communication with the expansion and exhaust chamber (**4**), to produce work.

5. Engine with the injection of an additional compressed non-polluting gas according to claim **4**, characterized in that the two parts (2A, 2B) of the expansion chamber (**2**) are in the form of nozzles where the driving chamber (2A) opens via a convergent section into a throat (2E) closed by the very high-speed shutter (2G) which allows it to be opened suddenly at the chosen moment in the cycle, and onto the working chamber (2B) via a divergent section such that the supersonic jet created when the throat is opened causes the formation of vortexes which, aside from the shock wave effects, make it possible to produce the desired pressure-increasing effects.

6. Engine with the injection of an additional compressed non-polluting gas according to claim **4**, characterized in that the driving chamber (2A) comprises a cathode (2H) which allows the driving gas to be ionized before it is introduced into the working chamber (2B), this having the effect of creating waves of electromagnetic nature, of increasing the intensity of the shock wave in the working chamber (2B), and of delaying the relaxation phenomena.

* * * * *

US006363723B1

(12) **United States Patent**
Negre et al.

(10) **Patent No.:** **US 6,363,723 B1**
(45) **Date of Patent:** **Apr. 2, 2002**

(54) **METHOD AND DEVICE FOR REACCELERATING A VEHICLE EQUIPPED WITH HIGH-PRESSURE AIR COMPRESSORS**

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(73) Assignee: **Guy Nègre** (FR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/284,144**

(22) PCT Filed: **Oct. 6, 1997**

(86) PCT No.: **PCT/FR97/01766**

§ 371 Date: **Jun. 7, 1999**

§ 102(e) Date: **Jun. 7, 1999**

(87) PCT Pub. No.: **WO98/15440**

PCT Pub. Date: **Apr. 16, 1998**

(30) **Foreign Application Priority Data**

Oct. 7, 1996 (FR) 96/12168

(51) **Int. Cl.**^{7} **F07B 75/02**; F02G 3/02
(52) **U.S. Cl.** **60/712**; 60/39.6; 180/302
(58) **Field of Search** 60/39.6, 712; 180/302; 123/22

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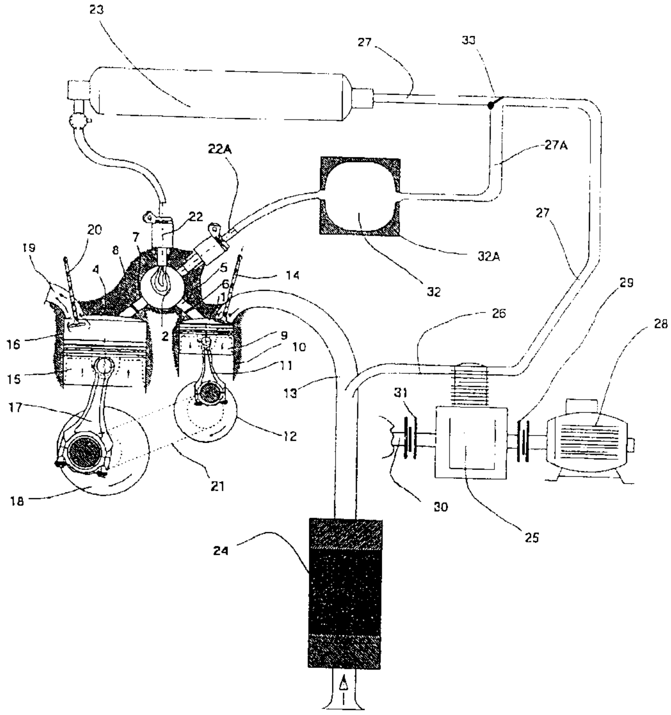
Primary Examiner—Michael Koczo
(74) *Attorney, Agent, or Firm*—Duane Morris; Arthur L. Plevy

(57) **ABSTRACT**

A method and device for reaccelerating a vehicle equipped with a compressor supplying high-pressure compressed air for cleansed or cleansing engine is provided, in which, during decelerating and/or braking phases, the on-board compressor being operated, the high pressure compressed air flow is derived and stored in a reaccelerating reservoir, thermally insulated and maintained at very high pressure and very high temperature, to be used when the vehicle is put back in driving phase by being injected at high temperature and at high pressure in the combustion chamber of the engine.

20 Claims, 2 Drawing Sheets



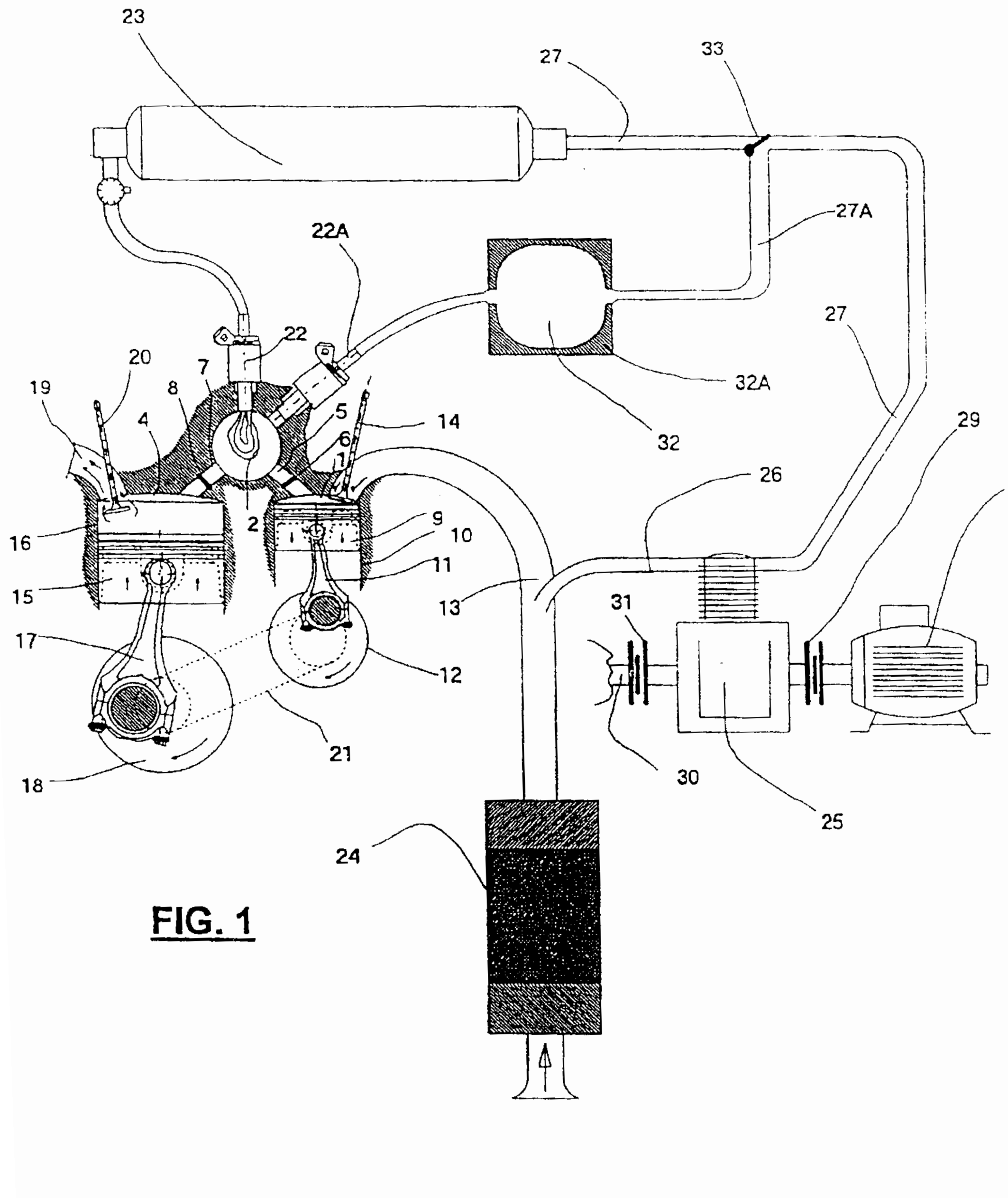


FIG. 1

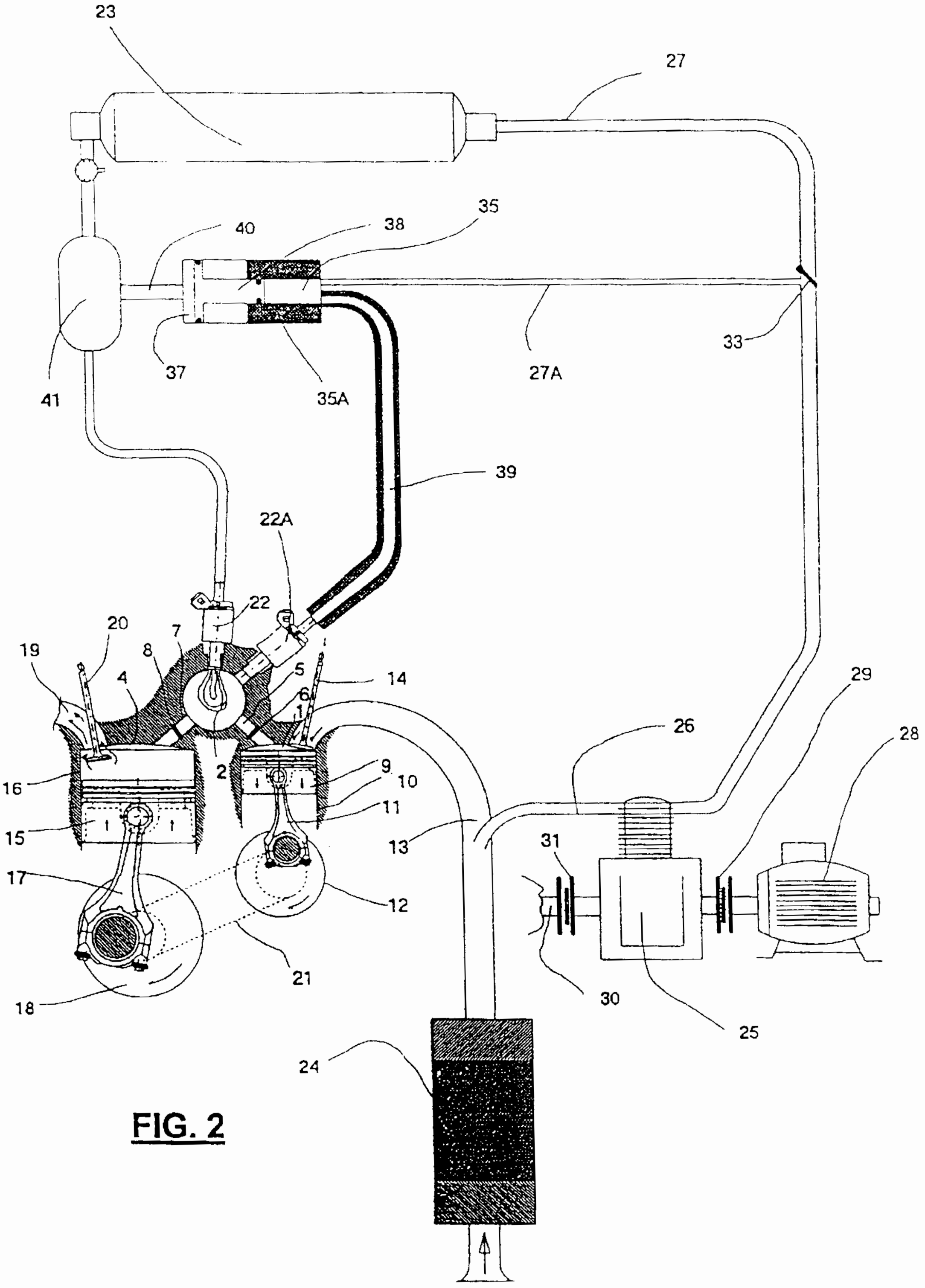


FIG. 2

METHOD AND DEVICE FOR REACCLERATING A VEHICLE EQUIPPED WITH HIGH-PRESSURE AIR COMPRESSORS

The invention relates to land vehicles, and, more particularly, those equipped with pollutant-free or pollution-controlling engines having an independent combustion chamber.

The author, in his published Patent Application WO 96/27737, described a method for the pollution control of an engine having an independent external combustion chamber, operating according to a bi-modal principle with two types of energy, using either a conventional fuel of the petrol or gas-oil type on the highway (mono-modal operation with air/fuel) or, at low speed, especially in urban and suburban areas, an addition of compressed air (or of any other non-pollutant gas), to the exclusion of any other fuel (mono-modal operation with air, that is to say with the addition of compressed air). In his French Patent Application 96/07714, filed on Jun. 17, 1996, now French Patent 2 749 882 the author described the installation of this type of engine operating mono-modally, with the addition of compressed air, on service vehicles, for example urban buses.

In this type of engine, in the air/fuel mode, the air/fuel mixture is sucked up and compressed in an independent suction and compression chamber. This mixture is then transferred, still under pressure, into an independent and constant volume combustion chamber, so as to be ignited there, in order to increase the temperature and pressure of the said mixture. After the opening of a transfer connecting the said combustion chamber to a depressurization and exhaust chamber, this mixture will be depressurized into the latter so as to carry out work there. The depressurized gases are subsequently discharged into the atmosphere through an exhaust pipe.

In low-power air operation, the fuel injector is no longer activated; in this case, a small quantity of additional compressed air, coming from an external reservoir where the air is stored under high pressure, for example 200 bar, and at ambient temperature, is introduced into the combustion chamber, substantially after the compressed air, without fuel, coming from the suction and compression chamber has been admitted into the said combustion chamber. This small quantity of compressed air, at ambient temperature, will heat up in contact with the high-temperature air mass contained in the combustion or expansion chamber and will expand and increase the pressure prevailing in the chamber, in order to carry out motive work during depressurization.

This type of bi-modal or bi-energy engine (air and petrol or air and additional compressed air) may also be modified for preferred town use, for example on all vehicles and, more particularly, on urban buses or other service vehicles (taxis, refuse lorries, etc.), in the air/compressed-air mono-mode, by omitting all the elements of the engine which operate with traditional fuel.

The engine operates, in mono-mode only, with the injection of additional compressed air into the combustion chamber which thus becomes a combustion chamber. Moreover, the air sucked in by the engine can be filtered and purified through one or more charcoal filters or filters using another mechanical or chemical method, a molecular sieve or other filters, in order to produce a pollution-controlling engine. The use of the term "air" in the present text refers to "any non-pollutant gas".

In his French Patent Application 9611632, the author also described the installation of on-board high-pressure compressors for recharging with compressed air the reservoir of the vehicle equipped with engines, such as those described above, the compressor being driven by an autonomous motor with an autonomous energy source and being engaged on the transmission in order to operate and replenish the reserves of compressed air of the vehicle during slowing and braking, thus making it possible to recover considerable energy dissipated during these operations.

However, in this type of installation, the high-pressure and high-temperature compressed air fills the main reservoir which is substantially at ambient temperature and is cooled. This solution causes the loss of a large part of its energy, especially when the reservoir begins to empty, thus bringing about a loss of its pressure due to depressurization.

The method according to the invention proposes another solution which makes it possible, in addition, to make available an additional torque and an additional power reserve during accelerations. It is characterized by the means employed and, more particularly, in that, during decelerations and braking, the high-pressure compressor, which is activated by a clutch or any other coupler, then serves as a retarder, or even as a brake, by generating compressed air at a high pressure of, for example, 200 bar and at high temperature. This compressed air is diverted and stored in a reservoir, heat-insulated or not, called the reacceleration reservoir, where the compressed air is maintained at high temperature and high pressure, so as to be utilized as soon as the vehicle is put into action again, by being injected into the combustion chamber of the engine. This compressed air, which has thus preserved most of its temperature and pressure due to the short dwell time in the reacceleration reservoir, is reinjected, hot, into the combustion chamber of the engine and provides a considerably larger amount of energy when the vehicle is put into action again or restarted. The capacity of the heat-insulated reacceleration reservoir, as well as the pressure of the air contained in it, is provided according to requirements, and, when the reacceleration reservoir is full, the air is once again diverted towards the main reservoir.

The average person skilled in the art can calculate the volume and pressure of the reacceleration reservoir as a function of the average frequency and average intensity of the brakings and accelerations, depending on the intended use.

According to a preferred characteristic of the invention, the reacceleration reserve is produced in a variable-volume system, in order, as soon as it begins to be filled, to maintain the compressed air stored in it at a virtually constant pressure and temperature, by means of a device assisted by mechanical, pneumatic or hydraulic systems, such as springs or the like, and, more particularly, by means of a device utilizing the compressed air under pressure in the main reservoir, after the said air has been depressurized to a specific pressure. This variable-volume heat-insulated reacceleration capacity thus prevents the falls in pressure and temperature of the compressed air while it is being filled and makes it possible, at any moment, to have available a quantity of air at the desired high pressure and at high temperature, so as to make it possible to put the vehicle into action again, without waiting until the reacceleration capacity is filled completely in order to reach the desired service pressure (for example, 100 bar).

Thus, shortly after slowing or braking, when the vehicle driver wants to reaccelerate, a quantity of compressed air at high pressure and high temperature, extracted from the reacceleration capacity, is injected into the combustion chamber, making it possible to obtain very high pressures in the said chamber, these being tokens of torque and power.

Numerous means for maintaining the temperature in the reacceleration reservoir may be employed, and mention may be made, for example, of: the use of ceramic or of a heat-insulating method, such as glass wool or the like, and it is conceivable to produce non-polluting thermal or chemical heating systems, without thereby departing from the method according to the invention.

Other objects, advantages and characteristics of the invention may be gathered from reading the non-limiting description of one embodiment, the said description referring to the accompanying drawings in which:

FIG. 1 shows a basic installation diagram including a reacceleration reserve according to the invention.

FIG. 2 shows a view in longitudinal section of a similar installation, with a variable-volume and constant-pressure reacceleration capacity and its system for maintaining pressure and temperature.

FIG. 1 shows, schematically, a basic installation diagram of a pollution-controlling engine comprising a suction and compression chamber **1**, a constant-volume combustion chamber **2**, in which is fitted an additional-air injector **22** fed with compressed air stored in a reservoir **23** under very high pressure, and a depressurization and exhaust chamber **4**. The suction and compression chamber **1** is connected to the combustion chamber **2** via a pipe **5**, the opening and closing of which are controlled by a leak-tight flap **6**. The combustion chamber **2** is connected to the depressurization and exhaust chamber **4** via a pipe or transfer **7**, the opening and closing of which are controlled by a leak-tight flap **8**. The suction and compression chamber **1** is fed with air via an intake pipe **13**, the opening of which is controlled by a valve **14** and upstream of which is fitted a pollution-controlling charcoal filter **24**.

The suction and compression chamber **1** operates as a to piston compressor assembly, in which a piston **9** sliding in a cylinder **10** is controlled by a connecting rod **11** and a crankshaft **12**. The depressurization and exhaust chamber **4** controls a conventional piston engine assembly, with a piston **15** which slides in a cylinder **16** and which causes the rotation of a crankshaft **18** by means of a connecting rod **17**. The exhaust of the depressurized air takes place via an exhaust pipe **19**, the opening of which is controlled by a valve **20**. The rotation of the crankshaft **12** of the suction and compression chamber **1** is controlled by the engine crankshaft **18** of the depressurization and exhaust chamber **4** via a mechanical connection **21**. The on-board compressor **25** has its air intake **26** branched to the intake pipe of the engine **13** between the filtering system **24** of the engine and the engine itself. During the rotation of the said compressor, it will fill the reserves of high-pressure compressed air **23**, installed on the vehicle, with compressed air via its exhaust pipe **27**. The compressor **25** is driven by an electric motor **28** via a clutch **29** which is actuated in order to fill the reserves.

The compressor **25** is also connected to the vehicle transmission **30**, likewise via a clutch **31** which will be actuated (engaged) during decelerations and brakings and which will serve as an engine brake, making it possible to slow the vehicle and fill a reacceleration reservoir **32 35** with high-pressure and high-temperature compressed air via a branched pipe **27A**, the said reacceleration reservoir advantageously being surrounded by a heat-insulating casing **32A**. A valve **33**, arranged on the exhaust pipe of the compressor **27**, diverts the compressed-air stream towards this reacceleration reserve via a branched pipe **27A**, by shutting off the pipe **27**, and, when the reacceleration reservoir is completely full, makes it possible, if necessary, for the on-board compressor to operate during braking and/or deceleration, via the pipe **27**, by shutting off the branched pipe **27A** and by directing the stream towards the main reservoir **23**. The valve **33** also shuts off the pipe **27A** during reacceleration, in order to convey the stream of compressed air under pressure, contained in the reacceleration reservoir **32** towards the reacceleration injector **22A**, when the on-board compressor **25** is disengaged, at the same time preventing pressure losses in the direction of the on-board compressor **25** and/or of the main external reservoir **23**.

After the deceleration, braking and/or stopping of the vehicle, during acceleration in order to put the said vehicle into action again, an air injector **22A** is actuated, so as to make it possible to inject high-pressure and high-temperature compressed air into the combustion chamber. This air will mix with the compressed air in the compression chamber **1** and is transferred into the combustion chamber of the engine, and will considerably increase the pressure, so as to have high power available for putting the vehicle into action again.

FIG. 2 shows a basic installation diagram, with a variable-volume reacceleration reservoir device according to a variant of the invention, with a pressure-regulating system managed by the compressed-air pressure prevailing in the main reservoir **23**. The reacceleration reservoir **35**, advantageously surrounded by its thermal insulation **35A**, consists of a hollow cylinder of small diameter, opening concentrically into a hollow cylinder of larger diameter **37**, a two-stage piston **38** sliding scalingly in the said cylinders. The cylinder of small diameter is the reacceleration reservoir **35**, connected to the intake pipe **27A** for high-pressure compressed air coming from the on-board compressor **25**, which is actuated during decelerations and/or braking, and to the pipe **39** for the outlet of compressed air towards the reacceleration injector **22A**. The cylinder of large diameter **37** comprises an intake **40** for medium-pressure compressed air which comes from the main reservoir under very high pressure **23** and which is depressurized in a medium-pressure buffer capacity **41** necessary and sufficient for feeding additional air to the injector **22** when the engine is operating normally.

The ratio of the diameters of the cylinders is calculated in such a way that the pressure depressurized into the cylinder of larger diameter **37** makes it possible, in the small cylinder, to maintain the selected pressure for feeding the reacceleration additional-air injector **22A**. For example, a large cylinder of a diameter of 100 mm, receiving a depressurized pressure of 40 bar, makes it possible to maintain a pressure of approximately 110 bar in a small cylinder of a diameter of 60 mm, which forms the reacceleration reservoir. So as to avoid a high pressure difference during the displacement of the piston **38**, the buffer capacity **41** will be selected so as to have a relatively large volume.

During operation in the compressed-air mode, the engine is fed with additional air, at 40 bar (for example) and at ambient temperature, by the additional-air injector **22**.

During a deceleration, that is to say as soon as the driver relaxes his pressure on the accelerator or during braking, the clutch **31** is activated and the on-board air compressor **25** is put into action and ensures slowing or braking. The diverting valve **33** is positioned so as to divert the air, compressed at high pressure (for example 150 bar) and high temperature by the compressor **25**, towards the reacceleration reservoir **35**. Under the effect of the intake of the compressed air via the pipe **27A**, the two-stage piston **38** is displaced and, by virtue of the force exerted on its face of large diameter by the pressure prevailing in the large cylinder **37**, maintains a virtually constant pressure (for example 100 bar) in the reacceleration reservoir **35**. When the piston **38** has reached the end of its travel, the valve **33** is actuated once again in order to direct the compressed air towards the main reservoir **23**. It is thus possible to slow and/or brake the vehicle, at the same time operating the on-board compressor **25** by directing the compressed-air stream in the direction of the main external reservoir **23**. As soon as the driver wants to reaccelerate, the reacceleration injector **22A** is actuated in order to feed hot high-compressed air to the combustion chamber **2**, thus making it possible to obtain a very high pressure, hence a high reacceleration torque, in the said chamber. In this operating phase, the valve **33** is positioned in such a way that it shuts off the branched pipe **27A**, in order to make it possible to convey the stream of compressed air under pressure, contained in the reacceleration reservoir **35**, towards the reacceleration injector **22A** while the on-board compressor **25** is disengaged, thus preventing pressure losses in the direction of the on-board compressor **25** and/or of the main external reservoir **23**. It is within the normal province of the average person skilled in the art to integrate the injection and valve-actuating commands as a function of the braking and acceleration phases described.

The type of high-pressure on-board compressor, the type of control clutch, the type of heat insulation of the reacceleration capacity, the type of diverting valve **33**, the method of maintaining pressure, etc., and the various arrangements of the elements in the vehicle, may vary, without thereby departing from the scope of the present invention.

What is claimed is:

1. A reacceleration method for a vehicle equipped with a pollutant-free or pollutant-controlling engine, comprising an external combustion chamber (2), into which, in operation with air, a quantity of additional compressed non-pollutant gas, coming from a main external reservoir (23) in which this compressed gas is stored under high pressure and substantially at ambient temperature, is introduced substantially after the compressed air, without fuel, coming from a suction and compression chamber (1) has been admitted into the said combustion chamber, this vehicle also being equipped with a high-pressure on-board compressor (25) activated during decelerations and brakings, so as to fill the main external reservoir (23), wherein the air, compressed at high pressure by the compressor (25), is diverted to a reacceleration reservoir and stored in order to be maintained at high temperature and high pressure, and in that this air is utilized as soon as the vehicle is put into action again or restarted, by being injected into the combustion or expansion chamber of the engine (2).

2. The method according to claim **1**, wherein the storage of the compressed air is carried out at a set volume.

3. The method according to claim **1**, wherein the storage of the air is carried out at a variable volume, in order, as soon as filling commences, to obtain and maintain a virtually constant pressure and temperature of the air which are substantially close to those supplied by the on-board compressor.

4. The method, according to claim **3**, wherein the control of the increase and variation of the volume of stored air utilizes the compressed air of the main external reservoir (23).

5. The method according to claim **1**, wherein the reacceleration reservoir is thermally insulated or is produced from insulating materials in order to maintain a high temperature and pressure.

6. A device for implementing the method according to claim **1**, wherein the storage of the compressed air coming from the on-board compressor (25) is carried out in a reacceleration reservoir (32, 35) branched to the exhaust pipe (27) of the on-board compressor (25) between the said pipe and an injector (22A) positioned in the combustion chamber (2).

7. The device according to claim **6**, wherein the reacceleration reservoir is a reservoir of set volume (32).

8. The device according to claim **6**, wherein the reacceleration reservoir is of variable volume (35).

9. The device according to claim **8**, wherein the reacceleration reservoir consists of a hollow cylinder of small diameter (35) opening concentrically into a hollow cylinder of larger diameter (37), a two-stage piston (38) sliding in the said cylinders, whilst the cylinder of small diameter (35) is connected, on the one hand, to the intake pipe (27) for compressed air from the high-pressure on-board compressor (25) via a branched pipe (27A) and, on the other hand, to a reacceleration injector (22A), and in that the cylinder of larger diameter (37) comprises an intake (40) for medium-pressure compressed air which comes from the main reservoir under very high pressure (23) and which is depressurized in a buffer capacity (41), whilst the ratio of the diameters of the cylinders is calculated in such a way that the medium pressure prevailing in the cylinder of large diameter (37) makes it possible, in the small cylinder (35) which is the reacceleration reservoir, to maintain the selected high pressure for feeding the reacceleration additional-air injector (22A).

10. The device according to claim **6**, wherein the exhaust pipe of the on-board compressor (27) and the pipe (27A) branched towards the reacceleration reservoir are equipped with a valve (33) which makes it possible, on the one hand, during decelerations and/or brakings, to divert the air stream coming from the on-board compressor (25) in the direction of the main external reservoir (23), by opening the branched pipe (27A) and by shutting off the exhaust pipe (27) of the on-board compressor (25), and, on the other hand, to make it possible to shut off the branched pipe (27A), either in order to allow the free passage of the compressed-air stream in the direction of the main external reservoir (23) or, when the reacceleration reservoir (35) is full, to make it possible to utilize the on-board compressor (25) in order to slow and brake the vehicle, or, during reaccelerations, to convey the stream of compressed air under pressure, contained in the reacceleration reservoir (35), towards the reacceleration injector (22A), while the on-board compressor (25) is disengaged, thus preventing the pressure losses in the direction of the on-board compressor (25) and/or the main external reservoir (23).

11. The method according to claim **2**, wherein the reacceleration reservoir is thermally insulated or is produced from insulating materials in order to maintain a high temperature and pressure.

12. The method according to claim **3**, wherein the reacceleration reservoir is thermally insulated or is produced from insulating materials in order to maintain a high temperature and pressure.

13. The method according to claim **4**, wherein the reacceleration reservoir is thermally insulated or is produced from insulating materials in order to maintain a high temperature and pressure.

14. A device for implementing the method according to claim **2**, wherein the storage of the compressed air coming from the on-board compressor (25) is carried out in a reacceleration reservoir (32, 35) branched to the exhaust pipe (27) of the on-board compressor (25) between the said pipe and an injector (22A) positioned in the combustion chamber (2).

15. A device for implementing the method according to claim **3**, wherein the storage of the compressed air coming from the on-board compressor (**25**) is carried out in a reacceleration reservoir (**32**, **35**) branched to the exhaust pipe (**27**) of the on-board compressor (**25**) between the said pipe and an injector (**22**A) positioned in the combustion chamber (**2**).

16. A device for implementing the method according to claim **4**, wherein the storage of the compressed air coming from the on-board compressor (**25**) is carried out in a reacceleration reservoir (**32**, **35**) branched to the exhaust pipe (**27**) of the on-board compressor (**25**) between the said pipe and an injector (**22**A) positioned in the combustion chamber (**2**).

17. A device for implementing the method according to claim **5**, wherein the storage of the compressed air coming from the on-board compressor (**25**) is carried out in a reacceleration reservoir (**32**, **35**) branched to the exhaust pipe (**27**) of the on-board compressor (**25**) between the said pipe and an injector (**22**A) positioned in the combustion chamber (**2**).

18. The device according to claim **7**, wherein the exhaust pipe of the on-board compressor (**27**) and the pipe (**27**A) branched towards the reacceleration reservoir are equipped with a valve (**33**) which makes it possible, on the one hand, during decelerations and/or brakings, to divert the air stream coming from the on-board compressor (**25**) in the direction of the main external reservoir (**23**), by opening the branched pipe (**27**A) and by shutting off the exhaust pipe (**27**) of the on-board compressor (**25**), and, on the other hand, to make it possible to shut off the branched pipe (**27**A), either to allow the free passage of the compressed-air stream in the direction of the main external reservoir (**23**) or, when the reacceleration reservoir (**35**) is full, to make it possible to utilize the on-board compressor (**25**) in order to slow and brake the vehicle, or, during reaccelerations, to convey the stream of compressed air under pressure, contained in the reacceleration reservoir (**35**), towards the reacceleration injector (**22**A), while the on-board compressor (**25**) is disengaged, thus preventing the pressure losses in the direction of the on-board compressor (**25**) and/or the main external reservoir (**23**).

19. The device according to claim **8**, wherein the exhaust pipe of the on-board compressor (**27**) and the pipe (**27**A)

branched towards the reacceleration reservoir are equipped with a valve (**33**) which makes it possible, on the one hand, during decelerations and/or brakings, to divert the air stream coming from the on-board compressor (**25**) in the direction of the main external reservoir (**23**), by opening the branched pipe (**27**A) and by shutting off the exhaust pipe (**27**) of the on-board compressor (**25**), and, on the other hand, to make it possible to shut off the branched pipe (**27**A), either to allow the free passage of the compressed-air stream in the direction of the main external reservoir (**23**) or, when the reacceleration reservoir (**35**) is full, to make it possible to utilize the on-board compressor (**25**) in order to slow and brake the vehicle, or, during reaccelerations, to convey the stream of compressed air under pressure, contained in the reacceleration reservoir (**35**), towards the reacceleration injector (**22**A), while the on-board compressor (**25**) is disengaged, thus preventing the pressure losses in the direction of the on-board compressor (**25**) and/or the main external reservoir (**23**).

20. The device according to claim **9**, wherein the exhaust pipe of the on-board compressor (**27**) and the pipe (**27**A) branched towards the reacceleration reservoir are equipped with a valve (**33**) which makes it possible, on the one hand, during decelerations and/or brakings, to divert the air stream coming from the on-board compressor (**25**) in the direction of the main external reservoir (**23**), by opening the branched pipe (**27**A) and by shutting off the exhaust pipe (**27**) of the on-board compressor (**25**), and, on the other hand, to make it possible to shut off the branched pipe (**27**A), either to allow the free passage of the compressed-air stream in the direction of the main external reservoir (**23**) or, when the reacceleration reservoir (**35**) is full, to make it possible to utilize the on-board compressor (**25**) in order to slow and brake the vehicle, or, during reaccelerations, to convey the stream of compressed air under pressure, contained in the reacceleration reservoir (**35**), towards the reacceleration injector (**22**A), while the on-board compressor (**25**) is disengaged, thus preventing the pressure losses in the direction of the on-board compressor (**25**) and/or the main external reservoir (**23**).

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US006397579B1

(12) United States Patent

Negre

(10) **Patent No.: US 6,397,579 B1**

(45) **Date of Patent: *Jun. 4, 2002**

(54) **INTERNAL COMBUSTION ENGINE WITH CONSTANT-VOLUME INDEPENDENT COMBUSTION CHAMBER**

(76) Inventor: **Guy Negre**, Forum Aurèllia, Route du Val, Brignoles F-83170 (FR)

(*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/171,286**

(22) PCT Filed: **Apr. 14, 1997**

(86) PCT No.: **PCT/FR97/00655**

§ 371 (c)(1),
(2), (4) Date: **Apr. 19, 1999**

(87) PCT Pub. No.: **WO97/39232**

PCT Pub. Date: **Oct. 23, 1997**

(30) **Foreign Application Priority Data**

Apr. 15, 1996 (FR) 96 04890

(51) **Int. Cl.**^{7} **F02G 3/02**

(52) **U.S. Cl.** **60/39.6**

(58) **Field of Search** 60/39.6, 39.63

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(57) **ABSTRACT**

A cyclic internal combustion engine having at least one working piston and cylinder arrangement which includes separate compression, combustion, and expansion chambers that perform respective compression combustion and expansion cycles. The compression cycle is advanced up to 180° in relation to the expansion cycle, so as to extend the combustion cycle during the exhaust stroke to reduce the formation in the combustion cycle of polluting gases.

12 Claims, 5 Drawing Sheets

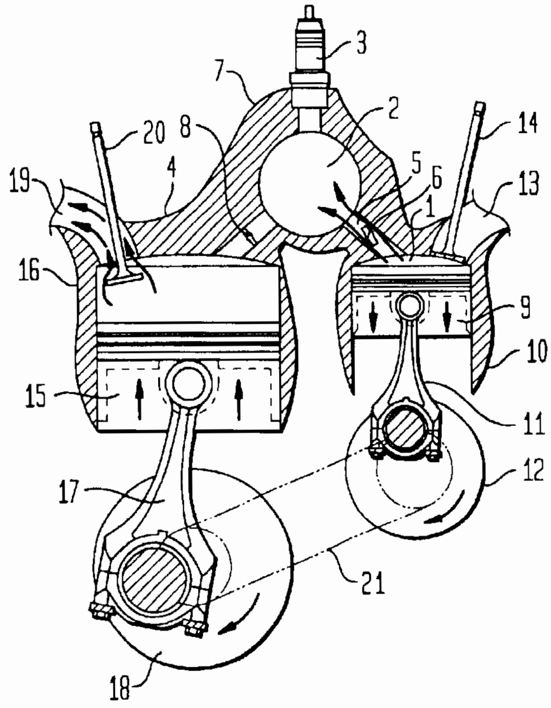


FIG. 1

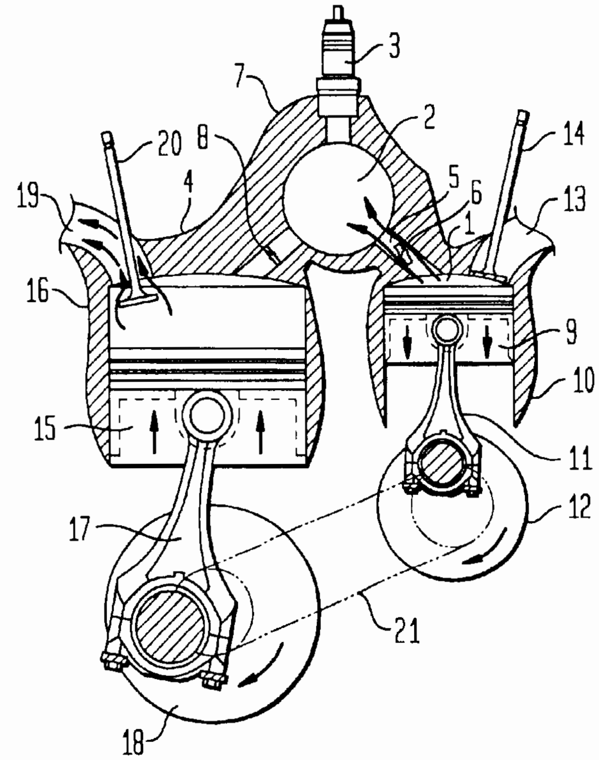


FIG. 2

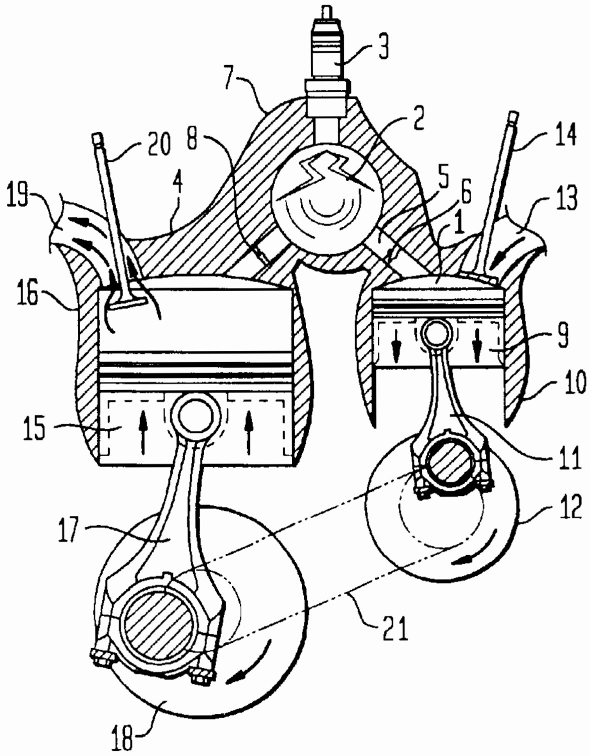


FIG. 3

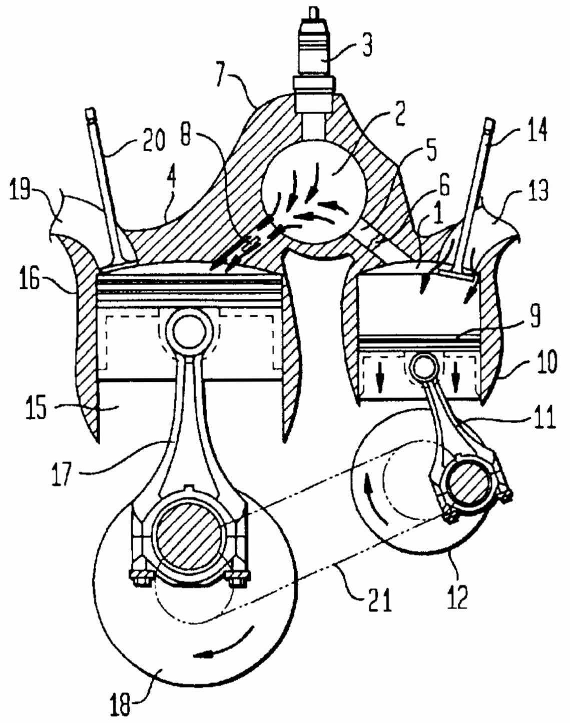


FIG. 4

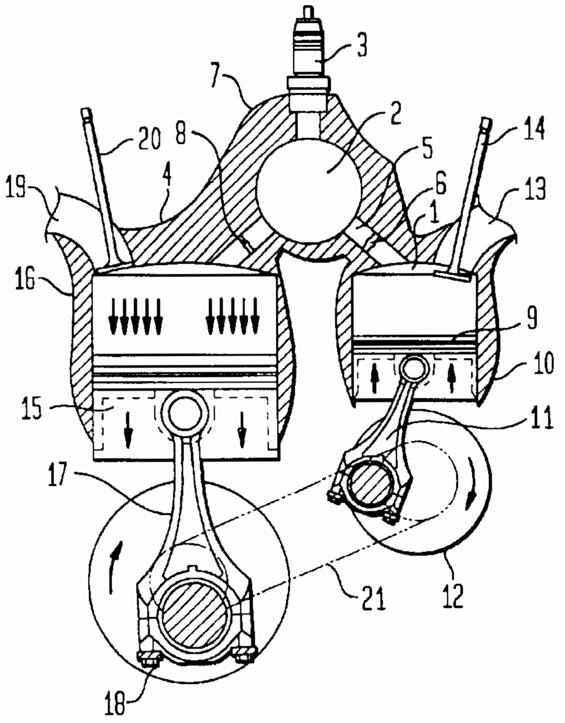


FIG. 5

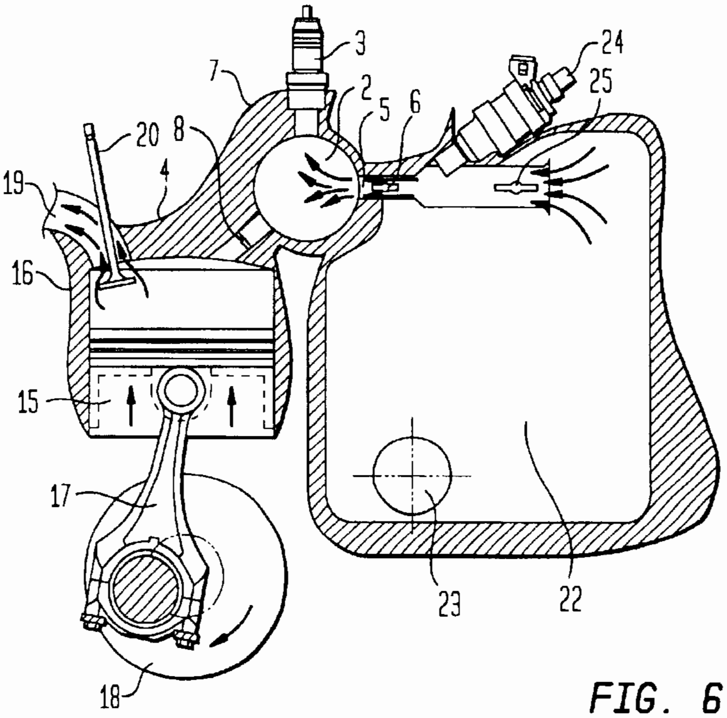


FIG. 6

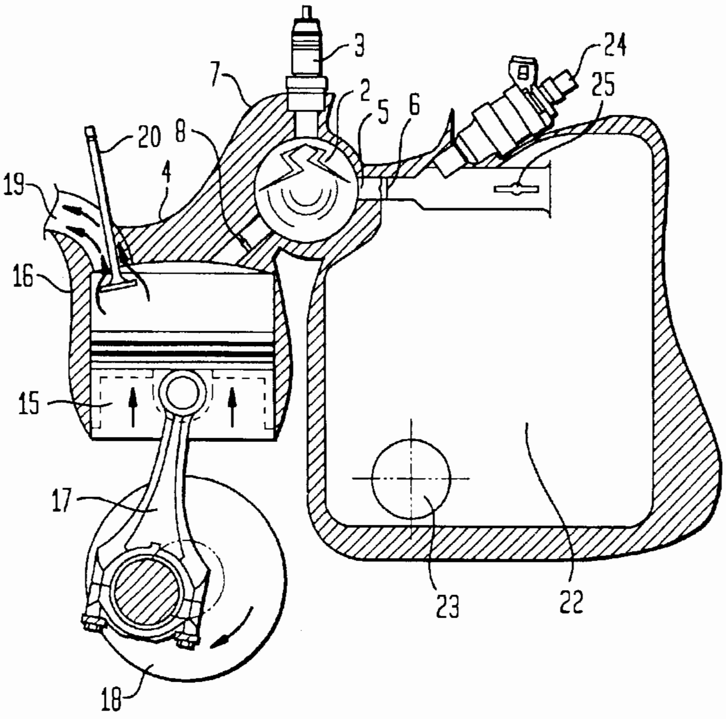


FIG. 7

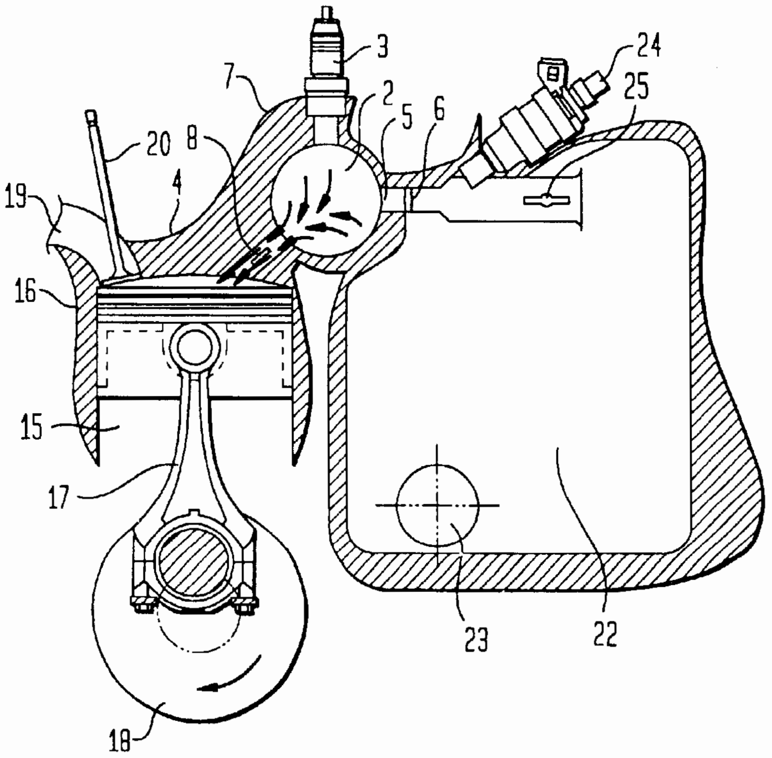


FIG. 8

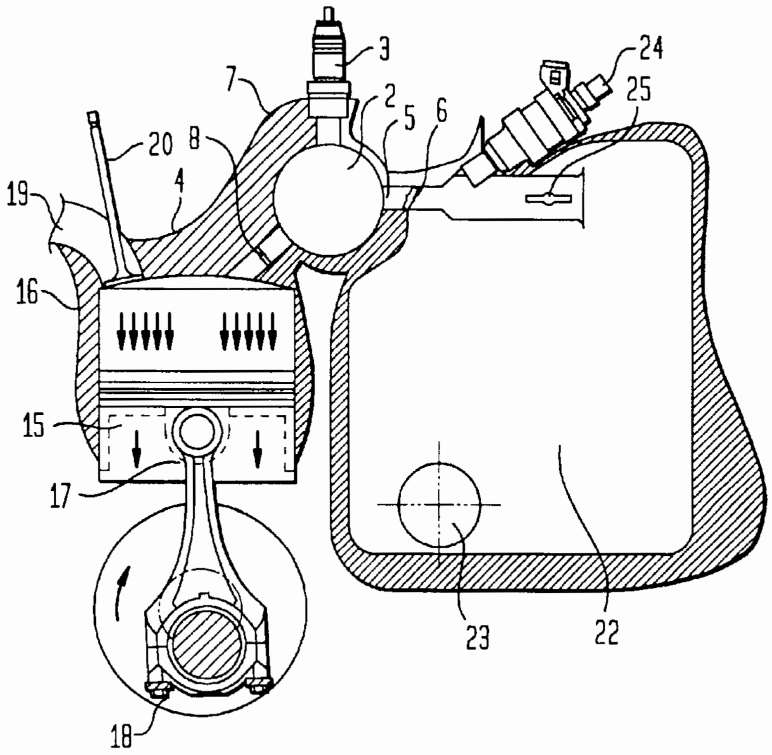
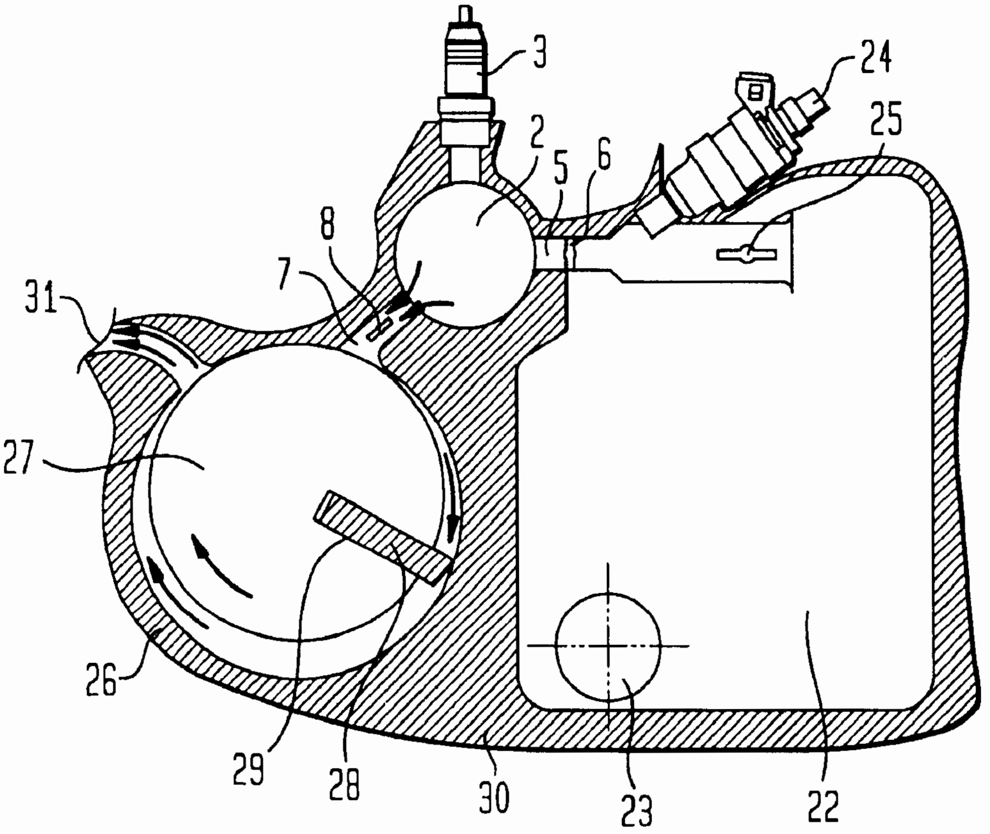


FIG. 9



INTERNAL COMBUSTION ENGINE WITH CONSTANT-VOLUME INDEPENDENT COMBUSTION CHAMBER

The invention relates to a cyclic internal combustion engine with an independent and constant-volume combustion chamber.

Cyclic internal combustion engines with an independent combustion chamber and separate compression and expansion chamber as described in French Patents 2319769 or alternatively 2416344 allow a certain number of improvements to be made to the operation compared with conventional engines. In this type of engine, inlet and compression take place in a chamber controlled by a piston, whereas expansion and exhaust take place in another chamber; the independent combustion chamber is connected to these chambers by ducts equipped with shutters. However, the variable volumes of these two chambers are controlled cyclically in phase and the time available for the combustion and transfer of the gaseous masses is particularly short and does not allow complete combustion to be achieved as is achieved in conventional engines.

The engine according to the invention makes it possible to alleviate this shortcoming and to make a considerable improvement in the operation of this type of engine; it is characterized by the means employed, and more specifically by the fact that the compression chamber cycle, which comprises inlet and compression, is advanced in relation to the expansion chamber cycle which comprises expansion and exhaust so that it is possible to obtain a combustion time which is far longer than in conventional engines; as a tangible example, in a conventional engine and in the engines described in the aforementioned patents, the combustion of their charge takes place over approximately 30 to 45° of rotation of their engine shaft, whereas with the engine procedure according to the invention there are up to 180° of rotation available (during the exhaust stroke) in which to fill the chamber and burn the mixture, and this, depending on the mode of filling used, may allow combustion periods of the order of 150° or even 160° of rotation of the engine shaft. Furthermore, and in order to avoid heat loss through the walls during this lengthy combustion, the chamber will or may be coated with a thermal barrier made of ceramic or other heat-insulating materials so as not to lose heat through the walls which can thus be very hot; likewise it will be particularly advantageous, this also for the same reasons, for the walls of the expansion chamber (piston crown, roof of the chamber, transfer duct, etc.) to be coated with a thermal barrier made of ceramic or other heat-insulating materials.

The operation of the engine according to the invention and the improvements made over conventional engines and over the engines described in the aforementioned patents will now be understood. The interdependency, in particular, in terms of compression chamber and expansion chamber cycle, and the thermal protection of the combustion chamber and/or of the expansion chamber allow combustion periods 3 to 4 times longer than those of conventional engines to be achieved without significant heat loss, and thus allow the efficiency to be improved; incidentally, it is also possible with this arrangement to be able to produce a combustion chamber which does not depend, at its base, on the diameter of the piston, and thus to approximate to or to achieve the ideal spherical shape without roughnesses or "corners" in which the gases do not burn and produce unburnt hydrocarbons.

These combined advantages of a long combustion period, of a compact combustion chamber shape close to that of a sphere without roughnesses or corners, thermally insulated with hot walls make it possible to obtain emissions of pollutants in the exhaust which are far lower than in conventional engines.

According to another embodiment of the invention, it is possible to form between the compression chamber and the combustion chamber a buffer volume in which compressed air is accumulated which will make it possible to avoid surge effects and pressure drops due to the dead transfer volumes and to the expansion during the filling of the combustion chamber.

The mode of operation of the compressor can therefore vary without this in any way altering the principle of the invention; although in common practice it seems convenient to employ a reciprocating compressor, any other mode of producing compressed air may be used—a single or multistage reciprocating compressor, a rotary vane compressor, a Roots-type blower or Lyshom type compressor or a turbocompressor driven by the exhaust gases. Likewise, for certain applications it is possible to employ a reserve of air from a cylinder (or other container) which will be expanded in the combustion chamber, or even compressed air from a main (in the example of a stationary engine used in a factory employing compressed air from a main).

The mode of operation of the expansion chamber can also vary without this in any way altering the principle of the invention; although in practice it also seems convenient to employ a piston sliding in a cylinder and driving a crankshaft via a connecting rod, any rotary encapsulation system can also be used—rotary with radial vanes, with rotary piston such as the path of a conchoid of a circle or of a trochoid, etc.

The engine according to the invention operates with homogeneous air-fuel mixtures and the mixing can be achieved using a carburetor prior to inlet into the compressor, but it is preferable to have a fuel-injection (electronic or mechanical) system between the compressor and the combustion chamber, although direct injection into the combustion chamber can also be used without that in any way altering the operating principle.

The engine according to the invention also operates with heterogeneous self-igniting mixtures like in diesel engines. In this case, the spark plug fitted into the chamber is omitted and a direct diesel injector supplied by a pump and its equipment of a type commonly used in diesel engines is fitted into the said combustion chamber.

Incidentally, there may be inserted at least two separate combustion chambers operating in exactly the same way as the one described hereinabove and which can be supplied together, separately or alternately in order to improve the thermodynamic efficiency at light load—for example using just one chamber for used power levels below half the total power of the engine, and using both chambers above that value.

Other objects, advantages and features of the invention will emerge from reading the non-limiting description of a number of embodiments, which description is given with reference to the appended drawings in which:

FIG. 1 depicts diagrammatically, seen in cross section, one embodiment of the engine according to the invention, in which the compression and expansion chambers are each controlled by a rod-crank system and a piston sliding in a cylinder,

FIG. 2 depicts this same engine after the air-fuel mixture has been introduced into the combustion chamber,

FIG. 3 depicts this same engine at the moment of transfer of the gases from the combustion chamber to the expansion chamber, FIG. **4** depicts this same engine during exhaust and compression,

FIG. **5** depicts another mode of operation, seen in cross section, in which a buffer volume in which compressed air accumulates is installed between the compressor and the combustion chamber, while the compressed air-fuel mixture is being let into the combustion chamber,

FIG. **6** depicts this same engine during combustion,

FIG. **7** depicts this same engine at the beginning of expansion,

FIG. **8** depicts this same engine at the end of expansion,

FIG. **9** depicts, in cross section, another embodiment, in which the expansion chamber is produced and expansion takes place in a rotary system of the type with radial vanes.

FIGS. **1** to **4** depict an embodiment of the engine according to the invention, in which the compression and expansion chambers are each controlled by a system comprising a rod and crank and a piston sliding in a cylinder, viewed in cross section, showing the compression chamber **1**, the constant-volume independent combustion chamber **2** in which a spark plug **3** is installed, and the expansion chamber **4**. The compression chamber **1** is connected to the combustion chamber **2** by a port **5** and the opening and closure of which are controlled by a sealed flap **6**. The combustion chamber **2** is connected to the expansion chamber **4** by a transfer port **7**, the opening and closure of which are controlled by a sealed flap **8**.

The compression chamber is supplied with compressed air by a conventional reciprocating-compressor unit: a piston **9** sliding in a cylinder **10** controlled by a rod **11** and a crankshaft **12**. The fresh air-fuel mixture is let in through an inlet port **13**, the opening of which is controlled by a valve **14**.

The expansion chamber **4** controls a conventional piston engine assembly: a piston **15** sliding in a cylinder **16** which, via a connecting rod **17**, rotates a crankshaft **18**, the burnt gases being discharged through an exhaust port **19**, the opening of which is controlled by a valve **20**.

The crankshaft **18** drives the compressor at the same speed via a connection **21** with an angular offset between the top dead center of the expansion piston and the top dead centre of the compressor piston, the latter being advanced by an angle chosen to suit the desired combustion period.

FIG. **1** depicts the engine when the compressor piston **9** is close to its top dead centre and the flap **6** has just opened to allow the constant-volume combustion chamber **2** to be supplied with fresh air-fuel mixture while the piston **15** of the expansion chamber **4** drives out through the exhaust **19** opened by the valve **20** the gases which were burnt and expanded in the previous cycle.

Continuing to rotate in the clockwise direction, FIG. **2**, the compressor piston **9** has just passed through its top dead center and begins its down-stroke; the flap **6** has just been closed and closes off the port **5**, the inlet valve **14** opens to allow replenishing with fresh air-fuel mixture from the compressor (inlet). As soon as the flap **6** closes, ignition is brought about by the spark plug **3** and the air-fuel mixture is burnt in the constant-volume independent chamber **2** while the expansion piston **15** continues its up-stroke and exhausts through the port **19**.

As the crankshafts **12** and **18** continue to rotate (here depicted about 100° later), the expansion piston **15** reaches its top dead center, the exhaust valve **20** closes again and the sealed flap **8** is made to open; the gases under very high pressure contained in the independent combustion chamber **2** expand through the transfer port **7** in the expansion chamber **7** and drive the piston **15** back, thus producing the power stroke, while the compressor piston **9** is in the process of completing the inlet of fresh air-fuel mixture.

Expansion will continue over approximately 180° crank angle, FIG. **4**; the sealed flap **8** is then closed again and the exhaust valve **20** opens, while the compressor piston **9** will compress the air-fuel mixture in the compression chamber **1** and the flap **6** will be opened to allow the new fresh air-fuel mixture into the constant-volume chamber **2** for the cycle to recommence (FIG. **1**).

It will be readily observed that each rotation of the crankshaft (engine and compressor) corresponds to an expansion (or power stroke) and that the choice of offset between the top dead center of the compressor piston **9** and the top dead center of the expansion piston **15** determines the period for the combustion of the mixture in the constant-volume combustion chamber **2**.

Incidentally, the expansion volume swept by the expansion piston **15** may be greater than the swept volume of the compressor **9**. This difference can be determined as a function of the differences between the polytropic compression and expansion curves with a view to obtaining the lowest possible pressure at the end of expansion, as this is a sign of good efficiency and low acoustic emissions.

FIGS. **5**, **6**, **7** and **8** depict, seen diagrammatically in cross section, another embodiment of the engine according to the invention, in which inserted between the compressor and the constant-volume combustion chamber **2** is a buffer volume **22** of compressed air, supplied with compressed air through a port **23** by any appropriate means and kept at an essentially constant pressure, and which has the effect of avoiding certain surge effects and the pressure drops due to the dead transfer volume and the expansion during the filling of the combustion chamber **2**. The port **5**, the opening and closure of which are controlled by the flap **6**, connects the buffer volume **22** of compressed air to the independent combustion chamber (**2**) and comprises a fuel injector **24** intended to perform the mixing of the air and the fuel somewhat before this mixture is introduced into the combustion chamber **2**. A flap **25** also situated in this port allows the charge let into the combustion chamber to be adjusted (accelerator).

FIG. **5** depicts the engine when the flap **6** has just been opened to allow compressed air mixed with fuel atomized by the injector **24** through the port **5** into the constant-volume combustion chamber **2** while the expansion piston **15** has just begun its up-stroke to drive out to the atmosphere, via the port **19** (the exhaust valve **20** having been opened) the gases which were burnt and expanded in the previous cycle, and while the transfer port flap **8** has just closed again.

As soon as the mixture has been introduced into the independent combustion chamber **2**, FIG. **6**, the flap **6** is closed again and the independent combustion chamber **2** finds itself isolated; ignition is then brought about using the spark plug **3** and the air-fuel mixture is burnt in the constant-volume combustion chamber **2** while the expansion piston **15** continues its up-stroke and exhausts through the port **19**.

The crankshaft **18** continues to rotate, FIG. **7**, the expansion piston **15** reaches its top dead centre, the exhaust valve **20** closes again and the sealed flap **8** is made to open. The gases under very high pressure contained in the independent combustion chamber **2** expand through the port **7** into the expansion chamber **4** and drive back the piston **15**, thus producing the power stroke.

Expansion will continue over about 180 degrees rotation of the crankshaft **18**, FIG. **8**, the sealed flap **8** is then closed again and the exhaust valve **20** opens; from this moment, the flap **6** is opened to let a new charge of fresh air-fuel mixture into the constant-volume chamber **2** so that the cycle can recommence (FIG. **5**).

It will be observed that with the insertion of a buffer volume of compressed air, the principle of operation of the engine remains the same. However, the air compressor becomes completely independent, no longer has to be set at a particular angle with respect to the engine crankshaft **18** and its choice of principle is thereby made easier. Furthermore, the greater the volume of this buffer, the more the effects of surging and pressure drops in the transfer volume and on expansion during the filling of the combustion chamber will be lessened.

FIG. **9** depicts another mode of operation of the engine according to the invention, in which the expansion chamber is built and expansion takes place in a rotating rotary encapsulation device of the radial vane type consisting of a cylindrical outer casing or stator **26** in which there rotates about an off center axis, a drum or rotor **27** tangential to the stator and equipped with a radial vane **28** which slides freely in its housing **29** to be pressed against the interior wall of the stator **26**, thus delimiting a variable volume between itself, the rotor and the stator, which volume increases from a low value that is practically zero near the generatrix of contact between rotor and stator. Pierced shortly after this generatrix and in the direction of rotation is the transfer port **7** (the opening and closure of which are controlled by the flap **8**) providing the connection between the constant-volume combustion chamber **2** and the expansion chamber. An exhaust orifice **31** is pierced, this time before the generatrix of contact between the rotor and stator, still in the direction of rotation. As soon as the vane uncovers the port **7**, the flap **8** is made to open and the gases under very high pressure contained in the combustion chamber **2** expand into the expansion chamber **30** and, pressing against the vane **28**, cause the rotor to rotate, while the vane **28** drives out in front of it toward the exhaust **31** the gases which were burnt and expanded in the previous cycle. Closure of the flap **8** and opening of the flap **6** allowing the fresh charge in the independent chamber **2** to be renewed will occur at the end of the expansion phase when the vane **28** is close to the exhaust port **31**.

The number of vanes and their positioning may vary, just as any other rotary system producing a rotating encapsulated system such as the path of a conchoid of a circle or a trochoid (rotary pistons of the Planche, Wankel, etc. type) can be used as an expansion chamber without that altering the principle of the invention which has just been described.

Of course, the invention is not in any way restricted to the embodiments described and depicted; it is susceptible to numerous alternative forms accessible to the person skilled in the art, depending on the envisaged application and without departing from the spirit of the invention.

What is claimed is:

1. A cyclic internal combustion engine comprising:

a compression chamber (1) having a first piston for performing a compression cycle defined by an inlet stroke and a compression stroke, the first piston connected to a first crankshaft;

a combustion chamber (2) for performing combustion;

an expansion chamber (4) having a second piston for performing an expansion cycle defined by an expansion stroke and an exhaust stroke, the second piston connected to a second crankshaft;

a connection for interconnecting the first crankshaft with the second crankshaft;

the chambers being separate from one another and connected by at least one duct equipped with a shutter;

means for generating an air-fuel mixture and delivering the mixture to the compression chamber (1) during the inlet stroke;

wherein an air-fuel mixture is compressed and ignited to produce a combusted air-fuel mixture to be expanded in the expansion chamber (4) when the expansion chamber (4) is generally at its smallest volume in order to produce work; and

wherein the beginning of each inlet stroke of a work cycle is advanced in relation to the beginning of each expansion stroke of an immediately previous work cycle, so as to extend combustion of the work cycle during the exhaust stroke of the immediately previous work cycle to reduce the formation of polluting gases during the combustion of the work cycle.

2. The engine according to claim **1**, wherein the combustion chamber has a generally spherical shape for obtaining, for a given volume, the smallest possible wall area with a view to avoiding heat loss through the said walls, and the shortest flame front distances, and the absence of "corners" where the air-fuel mixture does not burn and produces unburnt hydrocarbons.

3. The engine according to claim **1**, wherein the combustion chamber (2) is coated with a thermal barrier made of a heat-insulating material so as not to lose heat through walls of the combustion chamber which can thus be kept at a very high temperature and thereby enable the flame not to be quenched on the walls, thus avoiding the production of unburnt hydrocarbons in the exhaust gases.

4. The engine according to claim **3**, wherein the heat-insulating material comprises a ceramic.

5. The engine according to claim **1**, wherein walls of the expansion chamber (4) are coated with a thermal barrier made of a heat-insulating material so as not to lose heat through the walls of the expansion chamber which can thus be kept at a high temperature and improve expansion efficiency.

6. The engine according to claim **5**, wherein walls of the at least one connecting duct (8) between the expansion chamber and the combustion chamber (2) is coated with the heat-insulating material.

7. The engine according to claim **6**, wherein the heat-insulating material comprises a ceramic.

8. The engine according to claim **1**, further comprising a buffer volume of compressed air fitted between the compression chamber (1) and the combustion chamber (2), the buffer volume (22) of compressed air making it possible to avoid surge effects and pressure drops due to the dead transfer volume and to the expansion during the filling of the combustion chamber.

9. The engine according to claim **8**, wherein the at least one duct includes a connecting port (5), the connecting port (5) being located between the buffer volume (22) and the combustion chamber (2).

10. The engine according to claim **1**, wherein walls of the at least one connecting duct (8) between the expansion chamber and the combustion chamber (2) is coated with the heat-insulating material.

11. The engine according to claim **10**, wherein the heat-insulating material comprises a ceramic.

12. The engine according to claim 1, wherein the beginning of each inlet stroke of the work cycle is advanced up to 180° in relation to the beginning of each expansion stroke of the immediately previous work cycle.

* * * * *

page one of a 34-page patent
see: Popular Science, May 1971, "Cam-action air motor develops full torque at rest" by D. Scott

United States Patent [19]

Striegl

[11] **3,745,887**

[45] **July 17, 1973**

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[54] **ENGINE POWER UNIT**

[75] Inventor: **George Striegl,** Prescott, Ontario, Canada

[73] Assignee: **Temco Contact Ltd.,** Ottawa, Ontario, Canada

[22] Filed: **June 18, 1971**

[21] Appl. No.: **154,446**

[30] **Foreign Application Priority Data**

Mar. 31, 1971 Canada 109261

[52] **U.S. Cl.** .... **92/146,** 74/55, 74/56, 92/91, 123/56 C, 123/58 R

[51] **Int. Cl.** **F01b 1/00,** F16h 25/16, F02b 75/26

[58] **Field of Search** .... 123/58 R, 58 AB, 123/58 AM, 56 C, 56 R; 74/56, 55; 92/91, 31, 146, 467

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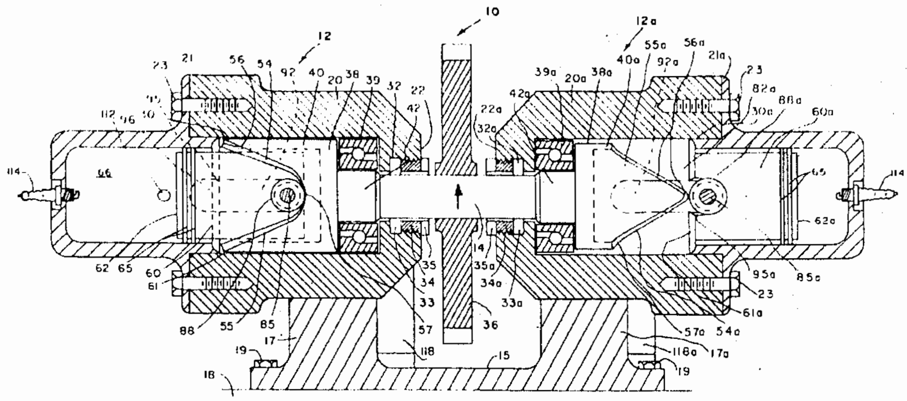
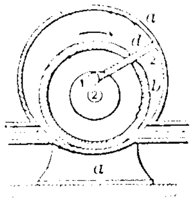
Primary Examiner—Wendell E. Burns
Attorney—Watson, Cole, Grindle & Watson

[57] **ABSTRACT**

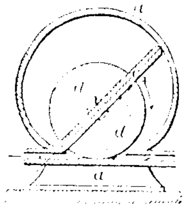
Disclosed is a power unit and engine wherein reciprocal motion of piston means are transformed into rotary motion of an output shaft without the aid of cranks and connecting rods. More particularly is disclosed a power unit which includes at least one cylinder piston assembly and an axially aligned rotor cam means connected to a drive shaft which means, in operative association with the piston which is guided for reciprocation only, transforms the reciprocal motion of the piston into rotary motion of the drive shaft. In the preferred form there is employed two substantially identical but opposed cylinder, piston and rotor assemblies in axial alignment, with means associated with the opposed pistons for causing them to reciprocate in unison. The opposed rotor means are connected to a unit shaft and are hollow, cylindrical rotors having annular cam surface means which in operative association with piston cam rollers transforms the reciprocal motion of the pistons into rotary motion of the unit shaft. The means for causing said pistons to reciprocate in unison comprises rod means between the pistons and slidably received within a bore through the unit shaft. The length of the rod means is such to control the separations of said pistons whereby a power stroke of one piston effects the return stroke of the opposed piston and maintains the cam rollers of the opposed piston in disengagement from the cam surface means of its associated rotor means during its return stroke. In addition is disclosed a steam engine with the operative association of a plurality of these power units about a common, central output drive shaft. Timed valve means control the flow of steam through the cylinders of the units and a mechanism is provided for advancing the valve means in response to an increase in rotation of the central drive shaft. Further a lubrication system is disclosed for such engine. When a power unit is adapted in an internal combustion engine, there is provided a power storage piston which stores energy from the initial impingement caused by firing the working fluid and which subsequently releases substantially all the stored energy during the power stroke of the piston whereby the sudden build-up of stress in the cam engaging surfaces is reduced.

29 Claims, 32 Drawing Figures

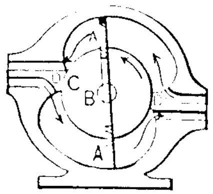




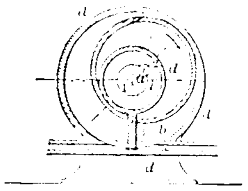
325. "COCHRANE" ROTARY ENGINE.—A wing piston rotating around the central axis of an outer shell or cylinder. A hollow cylinder of smaller diameter is pivoted eccentric to the wing axis to keep one side in contact with the shell. The steam pressure revolves the wing and shaft with a force due to the varying area of the wing outside of the inner cylinder.



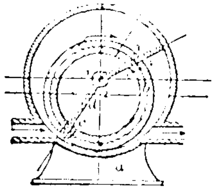
326. "FRANCHOT" ROTARY ENGINE.—A slotted concentric cylinder carries a continuous solid wing across and in contact with the interior surface of an ovoid shell, shaped for exact diameter in all directions on the eccentric axis of revo ution.



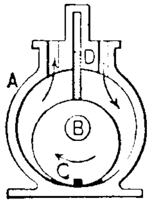
327. DOUBLE SLIDE PISTON ROTARY ENGINE.—In this engine the shaft and piston barrel are concentric, while the walls of the steam chambers are ovoid. A difficult form of construction.



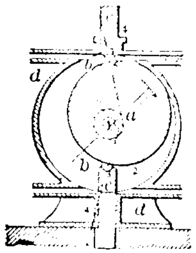
328. "LAMB" ROTARY ENGINE.—An annular cylinder with a fixed partition between the inlet and outlet. The piston is a hollow cylinder with a longitudinal slot, which slides up and down the partition, the outside of the cylinder wiping the inner surface of the shell. The centre of the traversing cylinder is pivoted to a crank pin, which carries it around a common centre shaft.



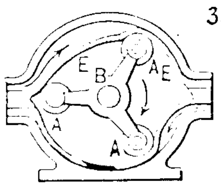
329. "COCHRAN" ROTARY ENGINE.—The wing pistons *d*, *d* are packed in the eccentric inner cylinder by a slotted rocking cylinder and revolve concentric with the outer cylinder or shell. The inner cylinder is pivoted eccentric to the shell, making a tight joint at the bottom.



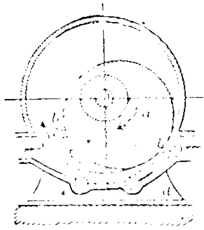
330. ROTARY ENGINE.—B, shaft; C, eccentric rotating piston; D, follower slide. The eccentric cylindrical piston operates the slide by its revolution.



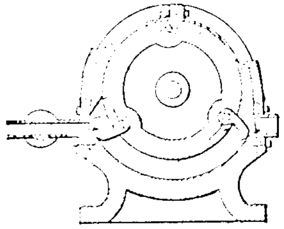
331. "NAPIER" ROTARY ENGINE.—An eccentric mounted cylinder on a shaft concentric with the shell. There are two sliding wings in slots in the shell, held to their bearings by springs or cam wheels on the shaft outside with connecting bars. There are two pair of ports.



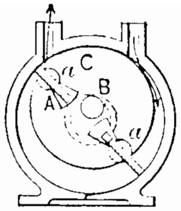
332. ROLLER PISTON ROTARY ENGINE. A rubber lining loosely placed within the cylinder is rolled over by the three-armed roller spider. E, E, rubber lining; B, spider on shaft; A, A, A, rollers.



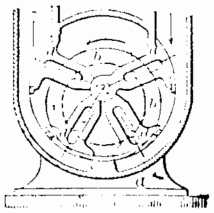
333. "COCHRANE" ROTARY ENGINE.—An eccentric cylindrical piston rotating on an axis central to the shell. The vibrating wings pivoted in the outer shell form the steam abutment by closing against the eccentric revolving cylinder.



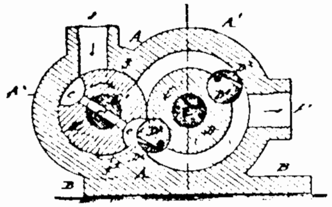
334. "BOARDMAN" ROTARY ENGINE.—A cylinder revolving concentric with an outer segmental cylinder, with pockets containing swing pistons that open by centrifugal action at the steam inlet, making a steam abutment across the segment. The swing pistons are closed at the exhaust port by contact with the small segment of the outer cylinder.



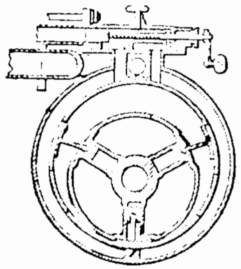
335. ROTARY ENGINE, with concentric shaft and wing barrel. The two wing slides pass through cylindrical rockers to give the slides a slight oscillating motion; slides are kept extended by pins traversing a circular slot concentric with the shell.



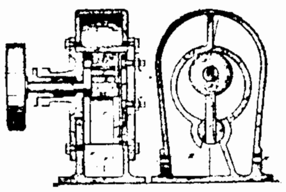
336. "SMITH" ROTARY ENGINE.—Four arms with cylindrical sectors are rotated around an axis central to a perforated cylindrical shell. The driven shaft and head discs are eccentric to the shell. The pressure of steam between the wings tends to push them apart, by which the differential leverage on the disc pins revolves the disc and shaft.



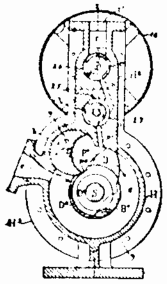
337. "BERRENBERG" ROTARY ENGINE.—Two intersecting cylindrical shells. The steam cylinder D has two cylindrical pistons, D', D', on opposite sides, that mesh in corresponding cavities in the cylindrical steam valve, both rotating in unison by equal external gearing. The steam port passes through the rotary valve E at the proper moment for the impulse. The supplementary sectors D² are hinged to the pistons D¹ to make a more perfect contact with the outer cylindrical shell.

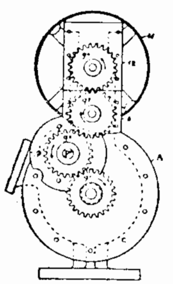


338. "FLETCHER'S" ROTARY CONDENSING ENGINE.—A hollow drum on a shaft eccentric to a double shell. Three slots carry slides and socketed arms as abutment wings, which are kept in contact with the cylindrical shell by a ring not shown. Steam ports on inner shell at the left side. Exhaust ports on the inner shell at the right.



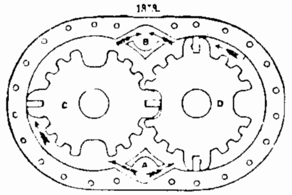
339. "BARTRUM & POWELL" ROTARY ENGINE.—A double shell divided for steam and exhaust. The inner shell cylindrical with a shaft and crank concentric. The crank pin carries a smaller winged cylinder, the wing sliding through a rocking joint. The end packing is made adjustable by a plate set up with screws. The crank pin has an eccentric sleeve which, by a slight rotation, compensates the wear of the rubbing surfaces.



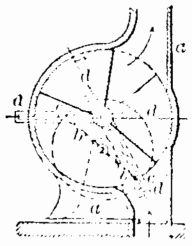


340. "RITTER" ROTARY ENGINE.—A revolving cylinder concentric with the shell, carrying an abutting lip or extension fitting the outer case. A revolving lunette controlled by gear on main shaft allows the lip to pass; a continuous gear train operates the valve.

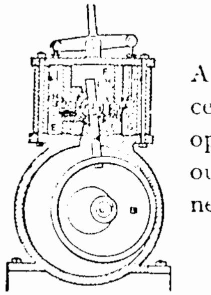
341. Exterior with valve gears



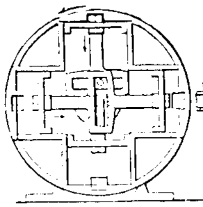
342. "HOLLY" ROTARY ENGINE.—The two geared pistons mesh their long teeth into the recesses of the opposite piston, thus making the sum of the radii between the centres less than the sum of the radii from each centre to its cylinder wall. Pressure rotates the gear in the direction of the longest leverage.

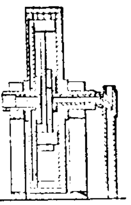


343. "STOCKER" ROTARY ENGINE.—The sector pistons are each connected through central concentric shafts to slotted cranks in which a sliding box and link connect to a crank on a shaft eccentric to the sector shaft. A differential motion of the sectors is produced while rotating which rotates the driven shaft by the outside slotted crank connections.



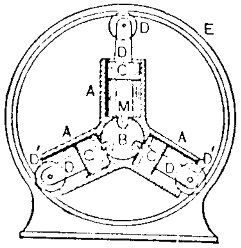
344. "FORRESTER" ROTARY ENGINE.—A cylindrical block and guard wing swing on an eccentric on the shaft. The guard wing slides in and operates the ports of a two-port rotary valve, the outer shell of which is operated by levers and connecting rods for reversing the engine.



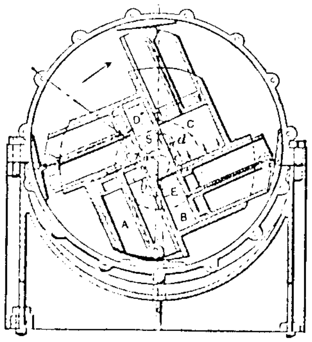


345. "KIPP" ROTARY PISTON ENGINE.—A broad pulley enclosing four single-acting cylinders with opposite pistons connected by yoked rods. A fixed crank pin and slide block placed eccentric to the pulley axis gives the propelling force by displacing the pistons successively. The steam follows through ports in a disc valve with inlet and exhaust through the hollow shaft.

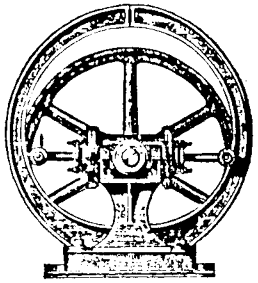
346. Section.



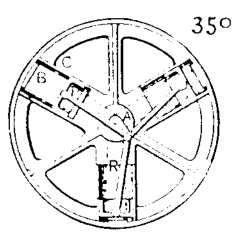
347. "RUTH'S" ROTARY ENGINE.—A revolving cylinder engine. Three cylinders, A, A, A, radiate from a shaft set eccentric to an outer circle or ring on which the piston connected sheaves revolve. The pistons take steam through the ports M, M, M, just past the shortest eccentric radius, and drives out the piston during a half revolution, when the exhaust is opened and the piston is pushed back by the eccentric ring.



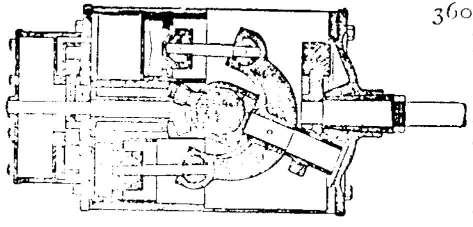
348. "ALMOND" ENGINE.—Four single-acting cylinders set tangent to a shaft which is central to an outer shell. The pistons have jointed segmental plates at their outer end that press against the outer shell and cause the cylinders and shaft to revolve by the eccentric direction of their pressure. Disc ports for steam and exhaust.



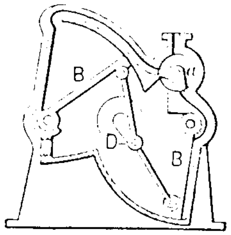
349. ROTATING CYLINDER ENGINE.—The cylinder rotates on trunnions with a through piston rod terminating with rollers running in an oval ring. Steam and exhaust ports in the trunnion. Pressure of the piston-rod rollers on the oval ring revolves the cylinder and fly-wheel on its runnion.



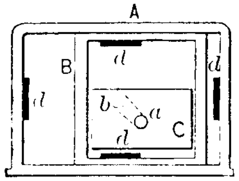
350. ROTARY MULTI-CYLINDER ENGINE.—Three or more cylinders are attached to and revolve with the fly-wheel. The crank is stationary and eccentric to the fly-wheel. Each cylinder is single-acting. Valves are on a central disc at A.



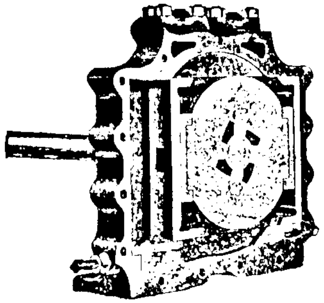
360. "KNICKERBOCKER" FOUR-PISTON ROTARY ENGINE.—A four-armed yoke is socketed on a centre common to the four pistons. Its spindle is a crank pin, and makes a conical circuit with the crank and shaft. The ends of the yoke are socketed to the pistons by connecting rods. The pistons take steam successively, making a continuous pressure on the circuit of the crank.



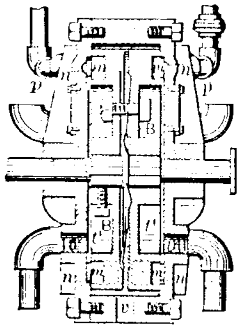
361. "ROOT'S" DOUBLE QUADRANT ENGINE.—In this design the two oscillating pistons are connected directly with the crank on the inside of the engine case, which is also the exhaust receiver. From the positions of the connecting rods at the end of the stroke of each piston the dead centre is eliminated.

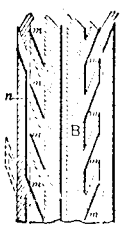


362. "ROOT'S" SQUARE PISTON ENGINE.—The oblong square box, A, is the cylinder proper. B, is a frame sliding freely in a horizontal direction by the force of the steam from the side ports, *d*, *d*. C is the inner rectangular piston, connected directly to the crank pin *a*, the shaft, *b*, being central to the range of the moving pistons. The piston, C, receives steam from the top and bottom ports, *d*, *d*, within the frame, B.



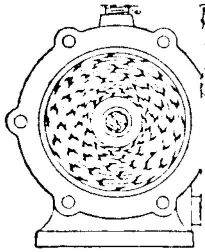
363. "DAKE" SQUARE PISTON ENGINE.—Two rectangular pistons, one within the other, working at right angles in the outer piston. The inner piston is connected to the crank pin, and moves vertically. The outer piston moves horizontally in the case. The principle is similar to the Root Square Engine, No. 362.

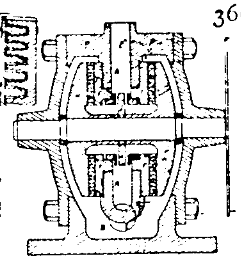




364. "WILKINSON'S" STEAM TURBINE.—Two rim-pocketed discs running against the disc surfaces of a shell with oblique steam ports. The discs are feathered on the shaft, and held against the faces of the shell by springs. A groove around the shell opposite the pockets allows the steam to pass around to the exhaust pipes.

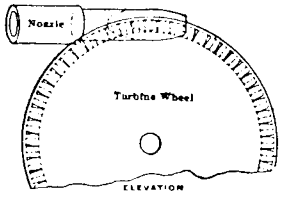
365. Section showing steam pockets.



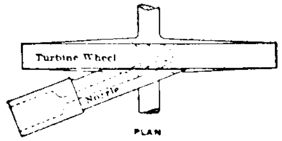


366. "DOW" STEAM TURBINE.—Two discs fixed to a shaft have on their face a series of circular grooves and tongues, meshed with a pair of fixed discs with grooves and tongues, as shown in small section 367. The tongues on the revolving discs are cut across at short distances in a slanting direction. The tongues on the stationary disc are cut in the opposite direction. The steam passes to the centre hub, and is forced through the openings across the tongues, giving motion to the discs and shaft.

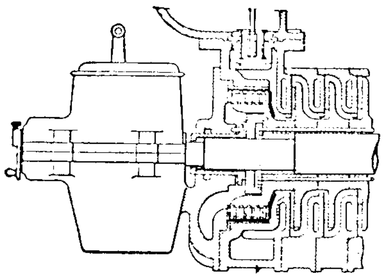
368. Vertical section of engine.



369. "DE LAVAL" STEAM TURBINE.—A jet or jets of steam impinge at a small angle upon the concave buckets at the periphery of a disc wheel, pass through the cavities between the buckets and exhaust at the other side. The buckets are lunette. The nozzle has an expanding orifice.



370. Plan showing nozzle at side of wheel.



371. "PARSONS'" STEAM TURBINE.—A series of discs fixed on a shaft with intersecting discs on the shell. The face of the shaft discs has several small blades set at an angle with the radius. The outside fixed disks have a similar set of blades interlocking with the revolving blades and set at a contrary angle. The steam passes from the valve to the inner edge of the first fixed disc, then outward through the blades, and returns through the vacant space of the next pair and outward again.

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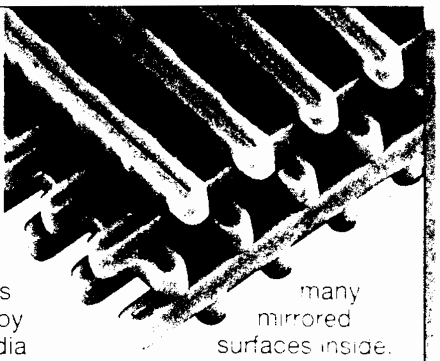
Technology Watch

Mirror Magic



A cheaper way to bend light entering or emerging from optical cables has been developed by scientists at Sandia National Laboratories in Albuquerque, N.M.

The microscopic device is made from tiny slivers of silicon (above) that are arranged much like toy Lincoln Logs. Because of this regularly repeating internal structure, researchers call it a photonic crystal.

The device traps light by bouncing it off the many mirrored surfaces inside.

"It is a monumental achievement," says Sandia manager Del Owyoung, "a fabrication that researchers have been trying to achieve for a decade."

Inventors Shawn Lin and Jim Fleming say that their next step will be to insert defects that will cause light to bend at desired angles.

Tree-Lovers Pen

BT's computerized pen could make memo pads obsolete.

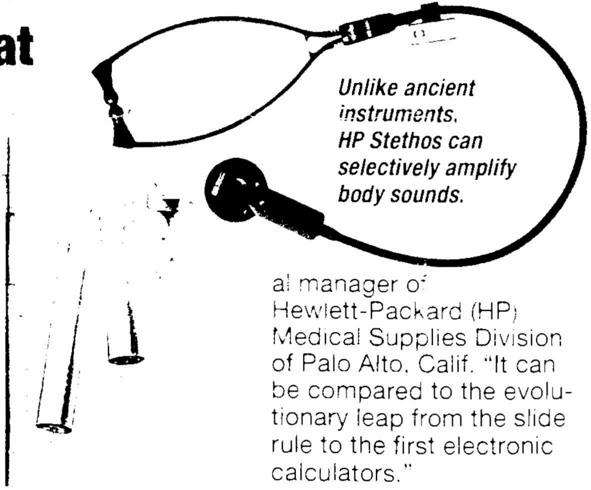
Developers of a tiny new computer that can read handwriting believe their SmartQuill could become the most revolutionary writing instrument since the pen.

SmartQuill can "read" anything written on paper or any other horizontal or vertical surface, including the air, says BT Laboratories in Ipswich, England (www.bt.com).

Accelerometers detect slight hand movements that a built-in computer then associates with specific letters or words. It can even recognize Chinese characters and its owner's signature. Information can be read off the pen, or transferred to a PC or printer, by inserting the pen into a digital "inkwell."

BT says it has no production plans, but has filed for patent protection.

High-Tech Heartbeat



Unlike ancient instruments, HP Stethos can selectively amplify body sounds.

Unchanged in more than 200 years, the acoustic stethoscope has been redesigned for 21st century physicians.

The new HP Stethos keeps the look and feel of the conventional instrument and adds sophisticated electronics. Among other things, the circuitry can amplify heart sounds 14 times more than a conventional stethoscope, dampen background noise and focus on specific frequency ranges.

"The transition from conventional stethoscopes to a fully electronic design represents a redefinition of this icon of medicine," says Jay Mazelsky, general manager of Hewlett-Packard (HP) Medical Supplies Division of Palo Alto, Calif. "It can be compared to the evolutionary leap from the slide rule to the first electronic calculators."

HP believes its new stethoscope will revive the ancient art of auscultation, or diagnosing disease by listening to organs.

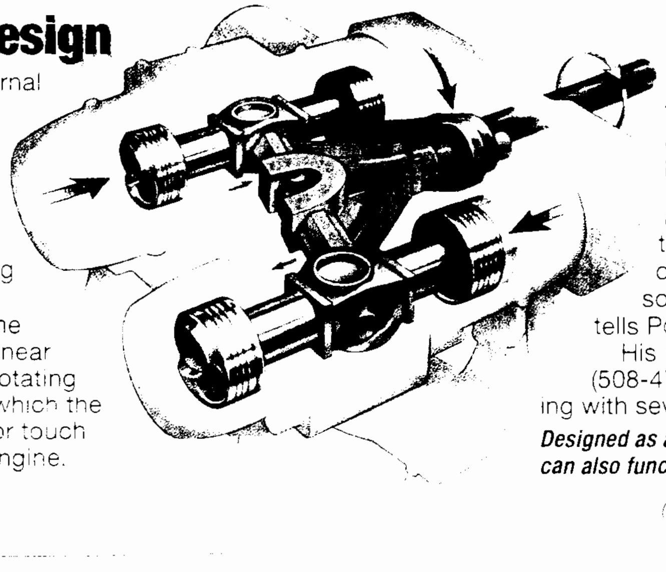
New Elements Created In Lab

Two new "superheavy" elements have been created at the Lawrence Berkeley National Laboratory in Berkeley, Calif.

Element 118 was created by bombarding a lead target with an intense beam of high-energy krypton ions. After a few milliseconds it decayed into element 116. Neither element has yet been named.

"Our unexpected success in producing these superheavy elements opens up a whole world of possibilities using similar reactions," says nuclear chemist Ken Gregorich.

Double Duty Design



Designed as a powerplant, the Sanderson Engine can also function as a gas pump or compressor.

A radically new type of internal combustion engine works just as well as a pump.

Named after its inventor, the Sanderson Engine replaces the familiar crankshaft and connecting rods with a one-piece connecting plate called a Nutator.

As the diagram shows, the Nutator (red) converts the linear motion of the pistons into rotating force. Varying the point at which the driveshaft (blue) and Nutator touch alters the engine's stroke engine.

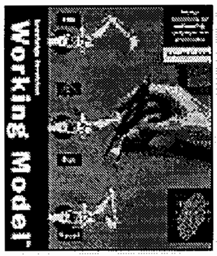
Preliminary tests of the 120-hp-plus engine suggest the new design can increase power by as much as 100 percent over diesel engines.

Attaching another engine or a motor to the driveshaft turns the engine into a highly efficient gas pump or compressor, inventor Bob Sanderson tells POPULAR MECHANICS.

His Upton, Mass., company (508-478-4454) is currently negotiating with several manufacturers.

(More Technology Watch on page 2?

Raccolta casi Working Model - Altro che bielle e manovelle, ecco il Nutator!



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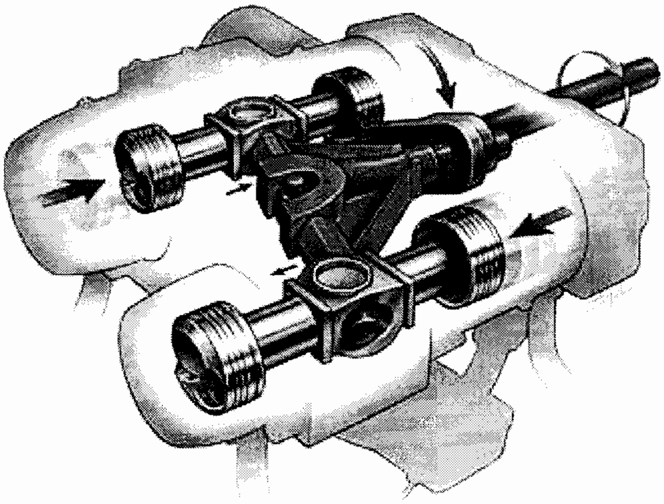
ALTRO CHE BIELLE E MANOVELLE, ECCO IL NUTATOR!

Una novità nel panorama dei motori a combustione interna: il Sanderson è l'alternativa al vecchio manovellismo di spinta.

RISTAMPA AUTORIZZATA DA "PROGETTARE", DICEMBRE 2001

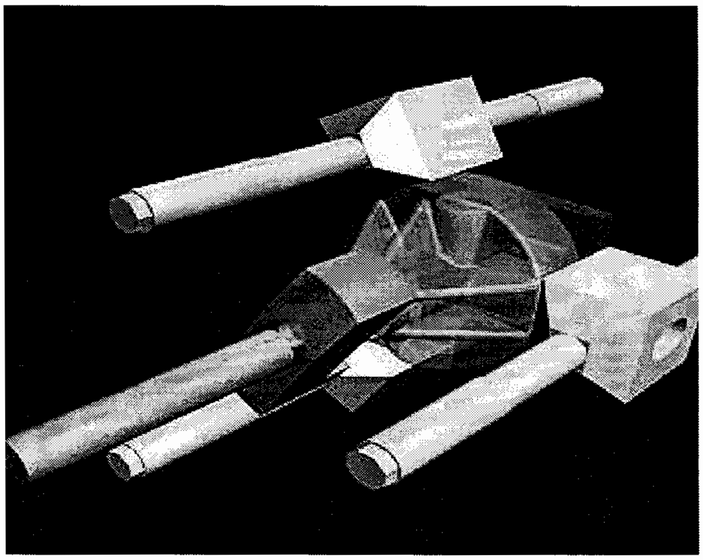
Dal nome del suo inventore, Bob Sanderson, la soluzione omonima sostituisce infatti a biella e manovella un nuovo membro, brevettato e battezzato Nutator.

Nutation:-"Movement by which an axis is made to describe a cone."(O.E.D.)



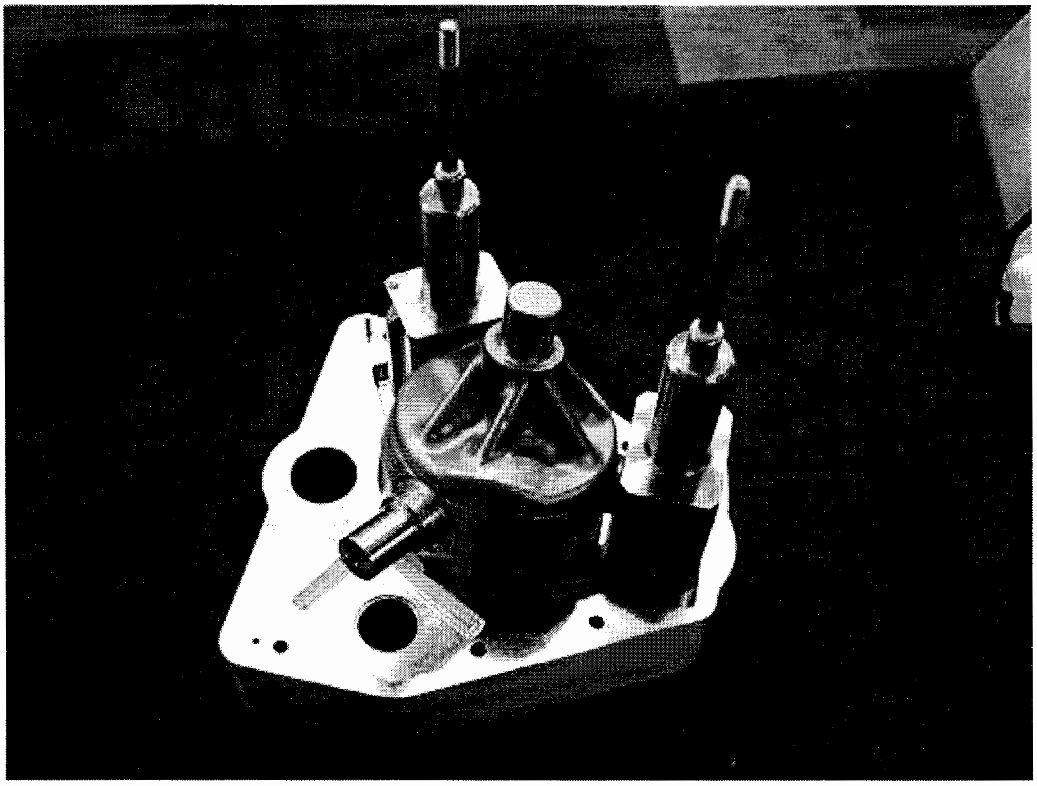
Come mostra l'immagine della soluzione bicilindrica, il Nutator (in rosso) converte il moto lineare dei pistoni in rotazione all'albero di trasmissione. Variando il punto di applicazione del Nutator all'albero (in blu) si può cambiare la corsa utile.

Accoppiando poi due unità di cui una motrice e l'altra operatrice, si può ottenere un'efficientissima pompa o compressore a motore termico, in cui uno stesso Nutator serve sia per la parte pompa che per la parte motore!



Grazie alla prototipazione virtuale con il software MSC.visualNastran 4D (già noto come MSC.Working Model 4D), la Sanderson Engine Development, Ltd. (SED), presso Upton nel Massachusetts, ha potuto risparmiare mesi di sviluppo nel delineare la nuova soluzione per il meccanismo di trasmissione ed aprire un nuovo capitolo per le applicazioni in altri settori.

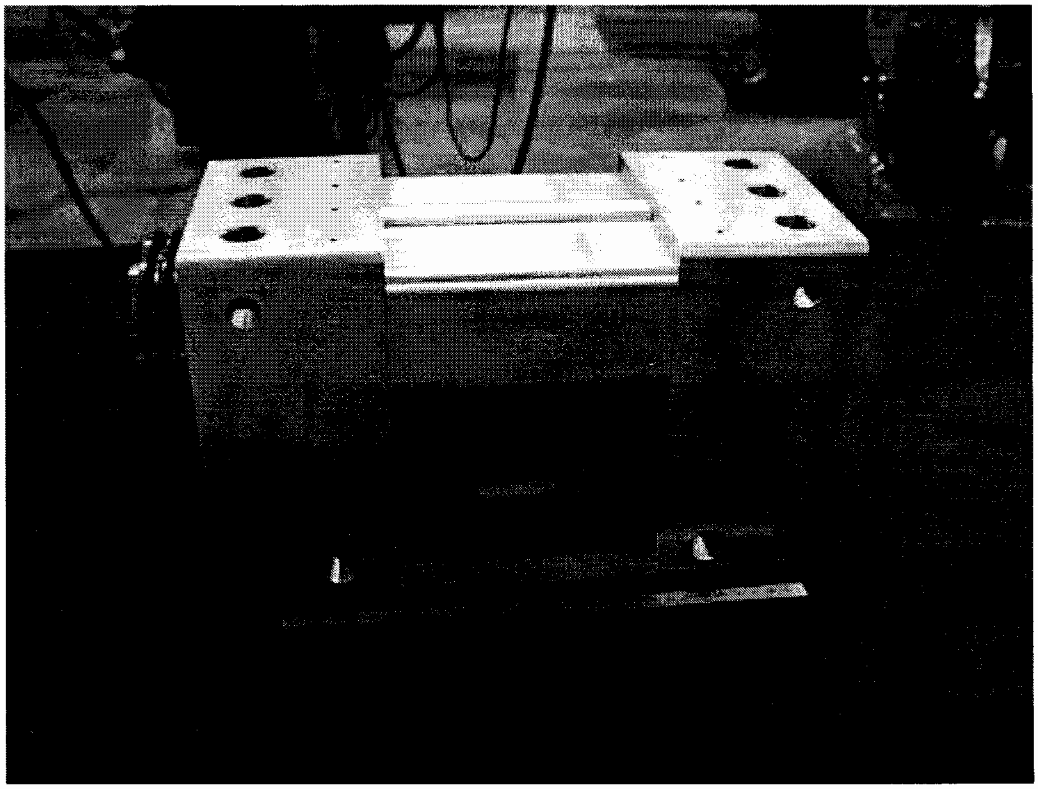
John Fox, general manager alla SED, riferisce che "abbiamo una nuova soluzione per il meccanismo di trasmissione del moto che richiede in effetti di pensare proprio in 3D per capire il suo funzionamento. Non è cosa semplice, ma il software MSC.visualNastran 4D ci ha messo in grado di dimostrare la fattibilità del concetto con un prototipo virtuale. Accelerando così la comprensione del nostro meccanismo, e allo stesso tempo verificando sforzi e deformazioni su parti e cuscinetti, siamo stati in grado di realizzare un processo di progettazione in cui è stato determinate e immediato il ruolo dei vari fornitori."



La SED, con il suo design innovativo che consente quasi di triplicare il rapporto potenza/peso sulle soluzioni Diesel convenzionali, sta creando un nuovo capitolo nella storia dei motori, delle pompe e dei compressori a pistoni. Non è escluso che di qui a poco tutti gli utilizzatori di questo basilare componente meccanico, quale il pistone, dovranno riconsiderare la loro produzione con la soluzione Sanderson. La SED sta infatti lavorando con vari fornitori per licenze di questa tecnologia in un grande numero di applicazioni, tra cui impianti di lavaggio auto, pompe ed idropulitrici, taglio a getto d'acqua, compressori per refrigeratori e motori Diesel.

Il vantaggio della soluzione SED consiste infatti nel modo con cui viene guidato il moto dei pistoni. Non è più necessario ricorrere a bielle e manovelle. Al loro posto, un organo meccanico innovativo, il Nutator, consente di realizzare motori, pompe o compressori che sono perfettamente bilanciati, riducendo al minimo gli attriti dovuti alle spinte laterali. In aggiunta, la compressione può essere modificata cambiando, in direzione lineare, la disposizione dell'albero di trasmissione.

William Rosa, ingegnere consulente presso la SED, afferma: "L'organo innovativo, il Nutator, appare come un cono con perni sul diametro esterno e ruota su un asse diverso da quello di simmetria geometrica. La parte posteriore del Nutator viene collegata ad un semplice giunto che oscilla sui piani XY e YZ. Il moto dei pistoni è puramente lineare. cosicchè questi risultano guidati senza l'introduzione di forze laterali. Nel classico manovellismo di spinta, invece, biella e manovella introducono spinte laterali indesiderate che dissipano energia per attrito, oltre a causare vibrazioni e rumore. La riduzione delle spinte laterali richiede l'uso di teste a croce e manovellismi più grandi, che ovviamente aumentano le inerzie e le dissipazioni. Soluzioni che infatti non vengono applicate nei motori automobilistici ma solo nei grossi impianti navali o statici."



Tra le varie applicazioni, al momento la SED si è indirizzata a tre settori specifici: pompe idrauliche, motori Diesel e accoppiamenti diretti motore/pompa.

Per ciascuna applicazione, le caratteristiche ed i benefici della soluzione con il Nutator si possono sintetizzare in:

Pompe idrauliche, caratteristiche

- meccanismo semplice e compatto per convertire moto roatorio in alternato lineare
- controllo continuo per la variazione del rapporto di compressione
- spinte laterali nulle
- moto dei pistoni sinusoidale (errore 1%)
- bilanciamento pressocchè perfetto
- riduzione del 20% degli attriti
- eliminazione delle teste a croce

Pompe idrauliche, benefici

- riduzione costi del 40%
- fino al 36% in meno di parti, grazie all'eliminazione di bielle, manovelle e teste a croce
- riduzione basamento e telaio
- pompe più leggere e compatte (fino al 50% in meno)
- riduzione di vibrazioni e rumore per migliore bilanciamento
- flusso più regolare grazie al moto sinusoidale dei pistoni
- capacità di rapporti di compressione più elevati a minor numero di giri
- maggiore varietà di taglie pompe per accoppiamenti diretti

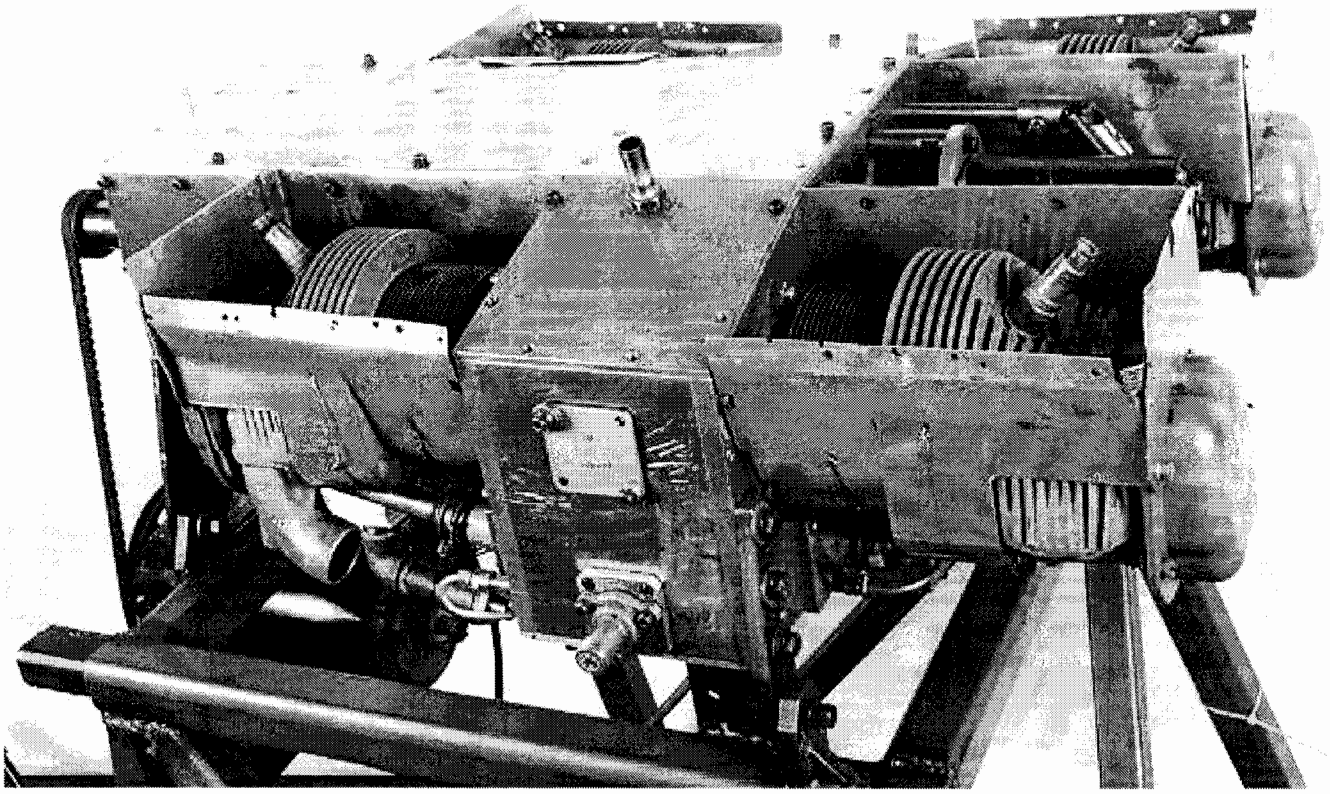
Motori Diesel, caratteristiche

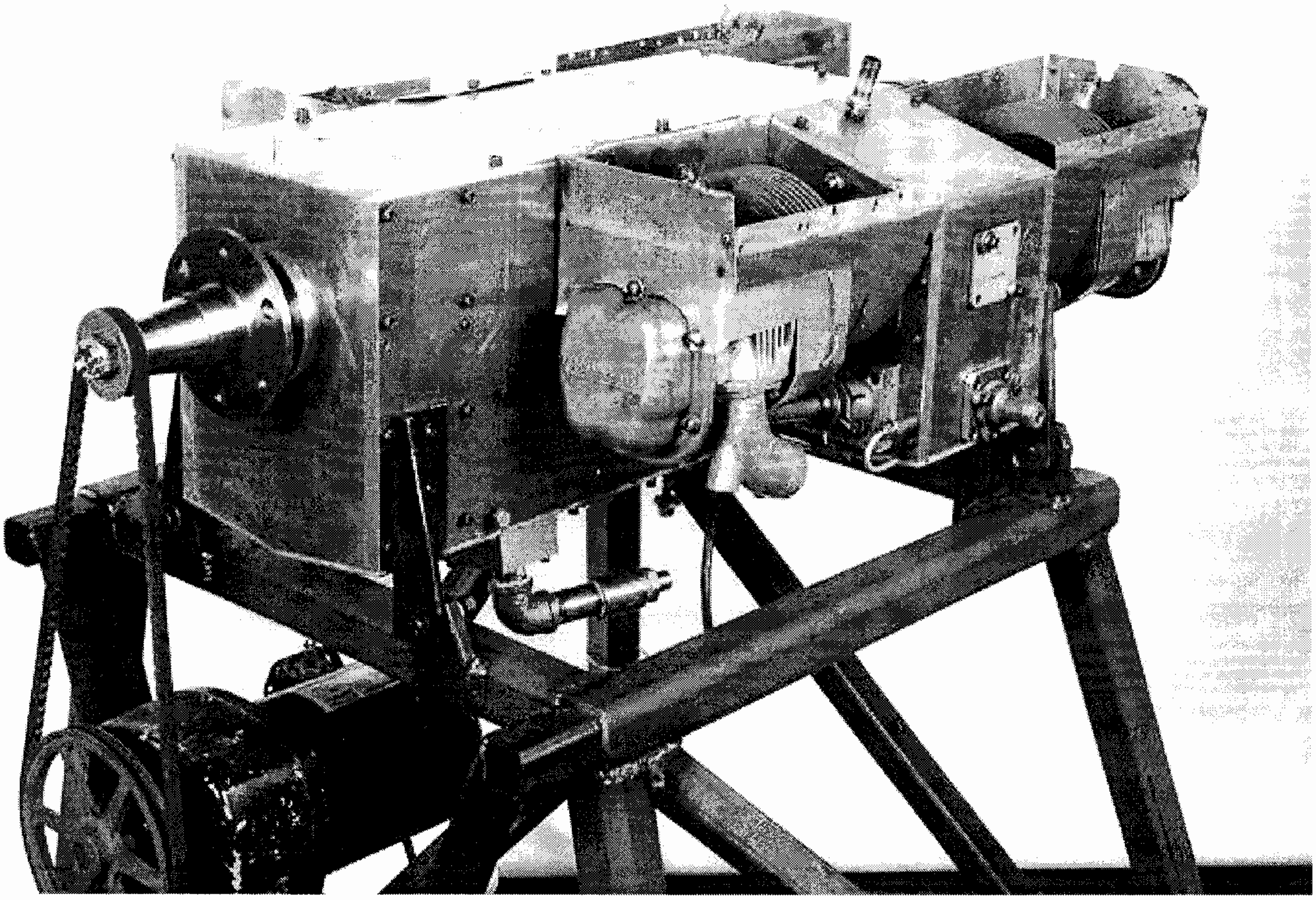
- meccanismo semplice e compatto per convertire moto roatorio in alternato lineare
- semplice soluzione a doppio effetto
- spinte laterali nulle
- moto dei pistoni sinusoidale (errore 1%)
- bilanciamento pressocchè perfetto
- riduzione del 20% degli attriti

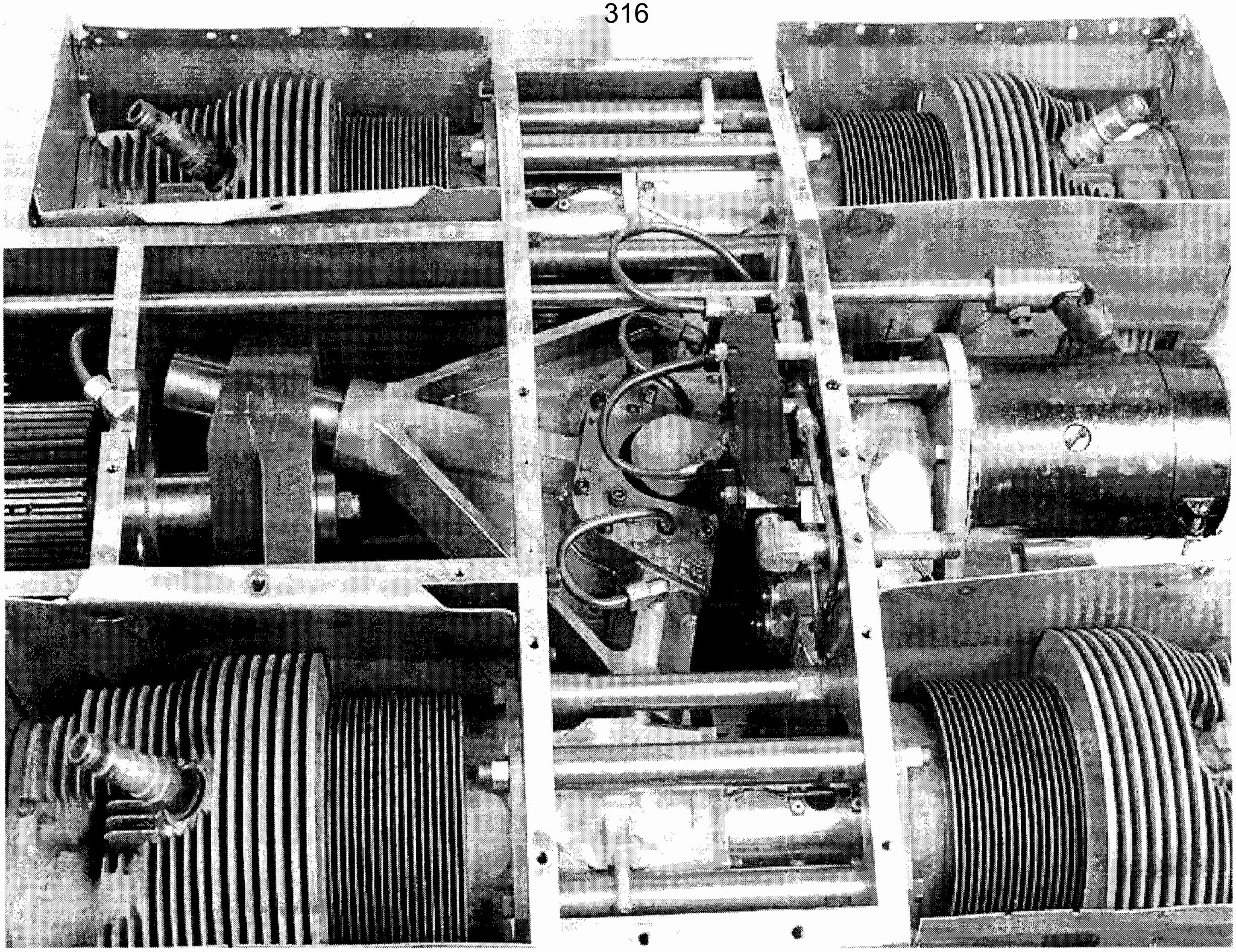
Motori Diesel, benefici

- aumento fino a 3 volte del rapporto potenza/peso
- riduzione degli NOx fino al 40%
- sostanziale riduzione nella emissione del particolato
- aumento di efficienza energetica fino al 13%
- riduzione dei costi di circa il 30%
- minori parti meccaniche, grazie all'eliminazione di bielle, manovelle e teste a croce
- circa il 50% di riduzione dell'ingombro motore
- riduzione delle vibrazioni per miglior bilanciamento e moto sinusoidale dei pistoni

Come esempio applicativo, le tre immagini seguenti presentano un motore a rapporto di compressione variabile sviluppato con la soluzione Nutator solution, come schematizzato nella prima illustrazione in testa a questa pagina. La SED ha usato in questo prototipo i cilindri di un motore aeronautico preesistente (Teledyne Continental O-200) per costruire rapidamente un prototipo fisico dopo la validazione virtuale fatta con il software MSC visualNastran 4D. Si tratta di un quattro tempi con rapporto di compressione che può essere variato da 7 : 1 a 12 : 1.







Accoppiamenti diretti motore/pompa, caratteristiche

- Lo stesso Nutator serve sia alla parte pompa che alla parte motore
- eliminazione delle teste a croce (quasi sempre presenti nelle pompe)
- spinte laterali pressocchè nulle
- accoppiamento in linea tra pistone pompa e pistone motore
- vbilanciamento pressocchè perfetto
- riduzione calore
- funzionamento regolarissimo per unità con più di due cilindri
- flusso regolare alla pompa

Accoppiamenti diretti motore/pompa, benefici

- riduzione costi di almeno il 30%
- efficienza meccanica fino al 98% rispetto al 70% circa delle unità accoppiate tradizionali
- riduzione pesi del 50%
- riduzione rumore e vibrazioni
- allungamento vita utile

Com'è stato possibile per la SED sviluppare l'idea del Nutator?

Innanzitutto, il software MSC.visualNastran 4D è stato utilizzato integrato nel CAD, in modo che le parti solide disegnate con SolidWorks venissero riconosciute senza possibili errori di conversione in formati di input/output. Le parti includevano il Nutator, i pistoni, i cuscinetti, l'abero, il volano e un giunto. L'ing. Rosa precisa: "Con un motore automobilistico c'è sempre qualcosa sbilanciato. Viceversa, con la soluzionev SED si può raggiungere il bilanciamento dinamico quasi perfetto. Pensiamo ad esempio di avere il modello di una pompa Sanderson in visualNastran. Basta mettere un vincolo matematico di motore visualNastran all'estremità del modello, in modo da trascinarlo, e misurare tutte le forze nei vincoli. Si può imputare l'azione del fluido sul cielo dei pistoni della pompa, inserendo ad esempio in visualNastran una forza con una funzione parametrica definibile dall'utente o interpolata con dati sperimentali. A questo punto è possibile ad ogni istante della simulazione cinetodinamica indagare su sforzi e sollecitazioni in ogni punto della macchina."

L'ing. Rosa continua, "MSC.visualNastran 4D ha fornito tutte le informazioni utili per il corretto dimensionamento del Nutator, che è il membro maggiormente sollecitato. Imputate le forze resistenti su ogni pistone, ho potuto visualizzare ad ogni istante della compressione il funzionamento del sistema, dopo aver correttamente bilanciato a vuoto il modello."

Uno degli obbiettivi della soluzione Sanderson è quello di allungare la vita utile della macchina. Pertanto è stato utilizzato nei calcoli un fattore di sicurezza 4. Continua l'ing. Rosa: "Al primo test virtuale con il visualNastran mi sono reso conto che le sollecitazioni erano molto elevate e che la soluzione originariamente disegnata al CAD era sottodimensionata. Il Nutator è stato così modificato per soddisfare la specifica di durata richiesta."

Costruire e provare un prototipo fisico è un approccio brutale, la cui risposta è solo sì o no. Ma non "come mai". In altre parole, se il test non viene superato non si può giudicare la serietà della non conformità. Grazie al prototipo virtuale, invece, la dinamica del sistema è immediatamente comprensibile e il giudizio qualitativo immediato. Continua ancora l'ing. Rosa: "Partendo solo da un prototipo fisico non avremo mai potuto capire il comportamento della soluzione ai vari carichi. Con la simulazione virtuale in visualNastran 4D possiamo cambiare qualsiasi grandezza e interattivamente analizzare le diverse sollecitazioni e deformazioni. Si esplora il funzionamento e la risposta della macchina in maniera esaustiva come non sarebbe certo possibile con un prototipo fisico. Se non si possiede questa informazione si è costretti ad esagerare con il fattore di sicurezza. Grazie al modello virtuale abbiamo potuto capire che quelle che ritenevamo applicazioni graduali di carico erano invece molto più repentinee, quasi impulsive, e abbiamo adeguato conseguentemente tutto il progetto."

"Elemento critico di tutto lo sviluppo ingegneristico è sempre la comprensione delle nuove soluzioni. La possibilità di analisi e documentazione fornita dal visualNastran, con il suo rendering fotorealistico dinamico associato all'analisi cinetodinamica e FEA, è stata imparreggiabile."

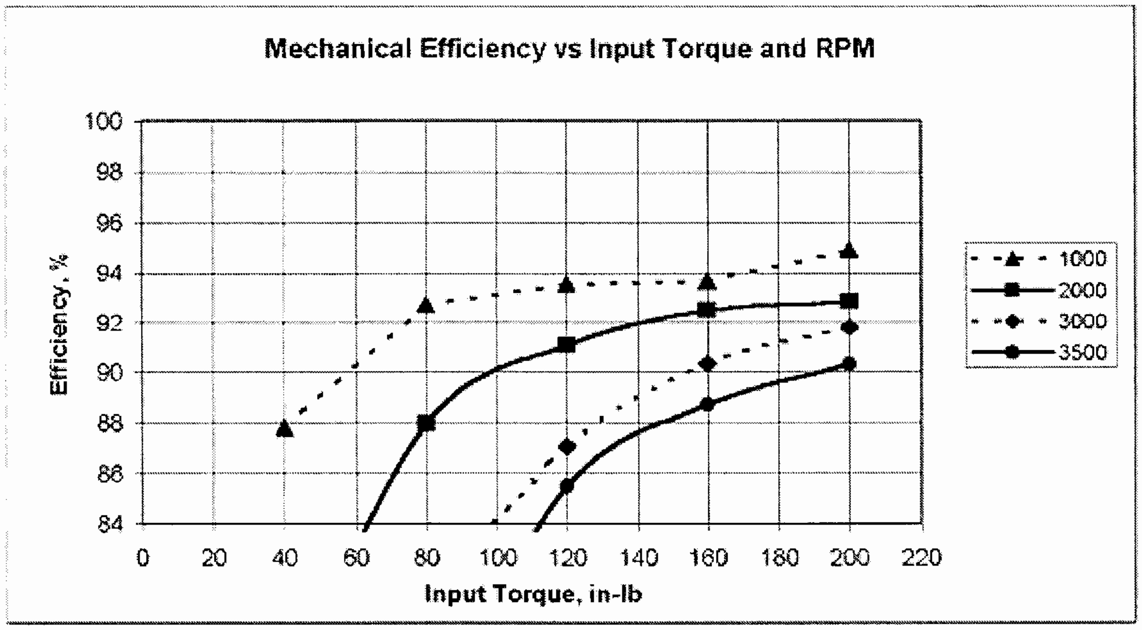
Il presidente della SED, Mr. Fox, conclude: "Abbiamo eliminato il manovellismo di spinta, ma sempre usando gli stessi pistoni, aste, valvole e tenute. La riduzione delle parti comporta un risparmio di peso anche del 50% rispetto ad una pompa convenzionale. Per giunta, il software MSC.visualNastran 4D è stato indispensabile non solo nella fase di calcolo ingegneristico, ma anche in quella di documentazione progettuale ed ha costituito con i suoi filmati il nostro linguaggio di scambio con le terze parti."

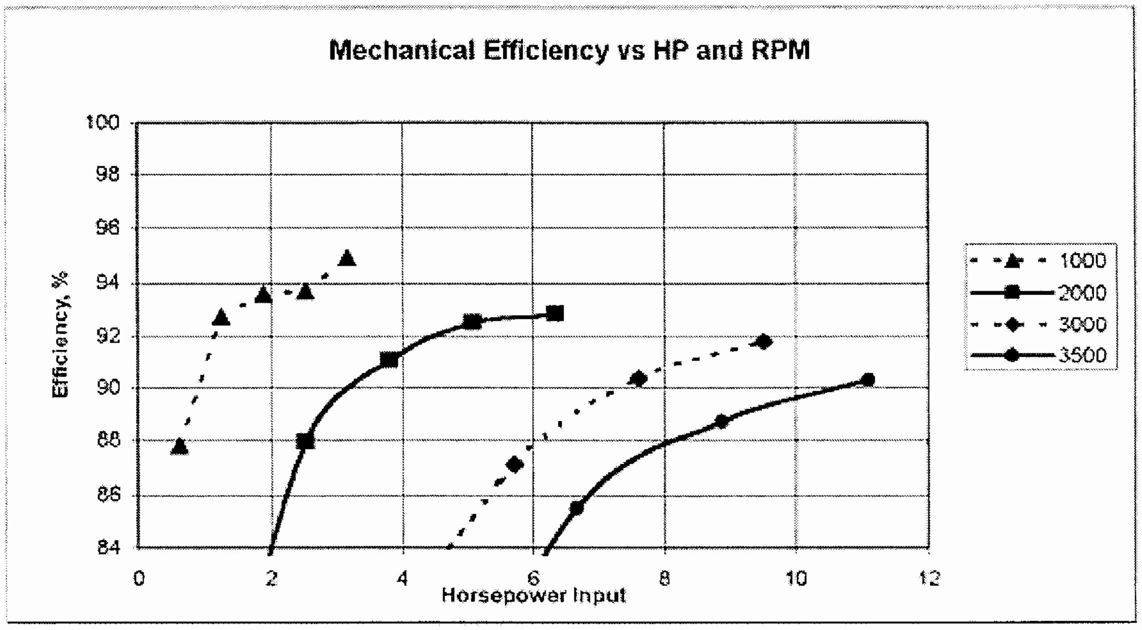
Efficiency vs. Torque and RPM

	1000	2000	3000	3500
40	87.8	77.0		
80	92.7	87.9	80.7	75.6
120	93.6	91.0	87.1	85.5
160	93.7	92.5	90.3	88.7
200	94.9	92.8	91.8	90.3

Efficiency vs. Horsepower and RPM

	1000	2000	3000	3500
40	0.63	1.27	1.90	2.22
80	1.27	2.54	3.81	4.44
120	1.90	3.81	5.71	6.66
160	2.54	5.08	7.62	8.89
200	3.17	6.35	9.52	11.11



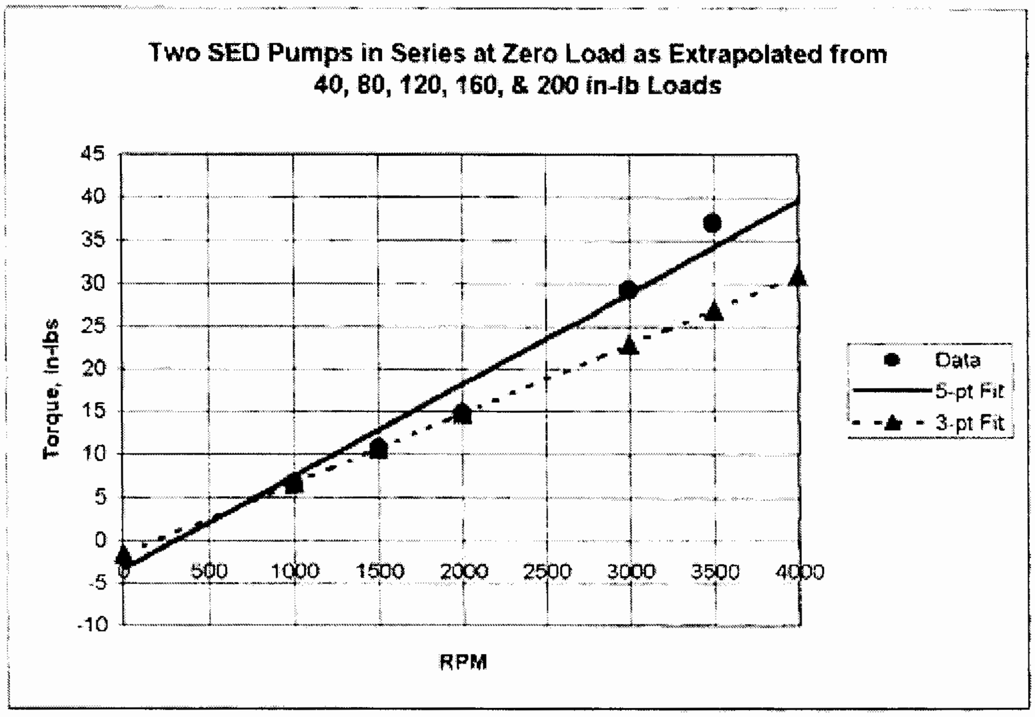


No-Load Test with Two SED Pumps in series.

No-load (zero torque) data extrapolated from torque required by two pumps in series at 40, 80, 120, 160, and 200 in-lbs

Input Torque	40	80	120	160	200
RPM	Out Loss	Out Loss	Out Loss	Out Loss	Out Loss
0	1.0	-1.1	6.6	12.3	12.9
1000	9.8	11.6	15.5	20.2	20.3
1500	13.5	14.7	18.2	21.3	22.6
2000	18.4	19.3	21.5	24.1	28.8
3000		30.8	31.0	30.9	32.9
3500		39.1	34.8	36.2	38.8
4000					

		5-point	3-point
	Intercept	-3.3	-1.6
	Slope	0.011	0.008
	Data	5-pt Fit	3-pt Fit
0	0	-3.3	-1.6
40	6.6	7.4	6.6
80	10.6	12.8	10.6
120	14.7	18.1	14.7
160	29.3	28.9	22.9
200	37.0	34.2	26.9
		39.6	31.0


Two SED Pumps in Series at Zero Load as Extrapolated from 40, 80, 120, 160, & 200 in-lb Loads

Riassumendo, i vantaggi della soluzione Sanderson sono:

Bilanciamento pressocchè perfetto

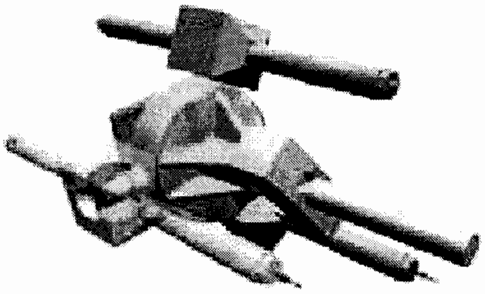
- una sola massa eccentrica di bilanciamento
- inerzie alterne lineari puramente sinusoidali (errore 1%)
- bilanciamento alterno genera pure un momento puramente sinusoidale
- complessità non significativa per bilanciamento completo
- inerzia ridotta per bilanciamento completo
- campi di velocità più estesi per migliore bilanciamento

Meccanismo con basso attrito

- dall'8 al 10% di migliore efficienza meccanica al banco prova
- dal 30 al 40% di riduzione attrito pistone (assenza spinte laterali)
- solo 3 cuscinetti fanno effettivamente 360° ogni giro motore
- altri cuscinetti molto meno critici rispetto a testa/piede bielle convenzionali
- possibile regime di rotazione più elevato
- minimo regolare intorno ai 300 rpm

Emissioni e consumi (Diesel)

- riduzione calcolata di circa il 13%
- nuovi rapporti e tempi di compressione consentono fino ad ulteriore riduzione del 3%
- un maggiore rendimento meccanico del 10% comporta quasi identica riduzione consumi
- emissioni NOx ridotte dal 25 al 40% per minori rapporti di compressione
- riduzione particolato per minori rapporti di compressione e diversi tempi iniezione



Fare click qui per scaricare il filmato AVI di questo motore Sanderson (2.8MB).

Fare click qui per un altro filmato AVI relativo al motore a 5 cilindri con regolatore (6MB).

ALTRI 60 CASI IN SETTORI DIVERSI !

Working Model®
The Motion Simulation Standard for Windows/NT
Lista Studio srl®
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